M Tech (Computer Science) Dissertation Series

ON LINE SEGMENT DETECTION IN IRS IMAGES

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CONTENTS

ABSTRACT

THIS REPORT PROVIDES THE RESULTS OF APPLYING VARIOUS LINE DETECTING ALGORITHMS ON I.R.S (INDIAN REMOTE SENSING SATELLITE) IMAGES. WITH THE RESOLUTION 36.25 x 36.25 sq.mt OF IRS IMAGES THE LINEAR FEATURES OF INTEREST TO US SUCH AS ROADS, RAILWAY LINES ARE IN GENERAL ONE, TWO OR THREE PIXELS WIDE.

THERE ARE MANY ALGORITHMS IN LITERATURE FOR DETECTING LINE SEGMENTS SUCH AS **SIMPLE THRESHOLDING[5], LINEAR AND NON-LINEAR LINE DETECTING OPERATORS[5], USING A PAIR OF EDGES[2].**

THIS REPORT DEALS WITH THE DETECTION OF LINE SEGMENTS USING THREE EARLIER METHODS IN RELATION TO TWO NEW METHODS. THE RESULTS ARE PROVIDED IN THE REPORT. THE IMAGES UNDER CONSIDERATION FOR ANALYSIS ARE I.R.S IMAGES OF CALCUTTA & BOMBAY.

ONE PIXEL WIDTH LINE SEGMENTS ARE DETECTED BY **'LINE TRACING'**. LINE SEGMENTS UPTO THREE PIXELS WIDTH ARE DETECTED USING THE **'CLASSIFICATION'** RESULTS OF THE IMAGES. THE CLASSIFICATION HAS BEEN DONE ACCORDING TO THE LAND COVER TYPE.

1 . INTRODUCTION

SOME OF THE FEATURES OF INTEREST IN ANY SATELLITE IMAGE ARE ROADS, RAILWAY LINES etc.,. THE PROBLEM OF INTEREST IN THIS REPORT IS THE DETECTION OF THESE STRUCTURES WHICH LEAD TO THE DETECTION OF LINE SEGMENTS. A FEW CONCEPTS ARE STATED BELOW IN THIS REGARD.

LINE [5]: THE GRAY LEVEL IS RELATIVELY CONSTANT EXCEPT ALONG A THIN STRIP. IN CROSS-SECTION, AN IDEAL LINE YIELDS A SHARP SPIKE AS SHOWN IN Fig A1a. BUT LINES OFTEN OCCUR IN ASSOSCIATION WITH EDGES (ROADS RUNNING BETWEEN FIELDS BEARING DIFFERENT CROP TYPES etc.,). AN IDEALISED VERSION OF THE RESULTING COMBINED CROSS-SECTION IS SHOWN IN Fig A1b.

EDGE[5]: THE GRAY LEVEL IS RELATIVELY CONSISTENT IN EACH OF TWO ADJACENT, EXTENSIVE REGIONS AND CHANGES ABRUPTLY AS THE BORDER BETWEEN THE REGIONS IS CROSSED. AN IDEAL EDGE HAS A STEP LIKE CROSS-SECTION AS SHOWN IN Fig A2a. A MORE REALISTIC EXAMPLE, INCORPORATES BLUR AND NOISE EFFECTS AS SHOWN IN Fig A2b.

TEMPLATE OPERATORS[2] : THE METHODS USED TO DETECT LINES AND EDGES CAN BE EXPRESSED AS TEMPLATE TECHNIQUES. A TEMPLATE IS A MASK OR WINDOW THAT IS MOVED OVER THE IMAGE ROW BY ROW AND COLUMN BY COLUMN, Fig A3a. THE PRODUCTS OF THE PIXEL BRIGHTNESS VALUES, COVERED BY THE TEMPLATE AT A PARTICULAR POSITION, AND THE TEMPLATE ENTRIES ARE TAKEN AND SUMMED TO GIVE THE TEMPLATE RESPONSE. THIS RESPONSE IS THEN USED TO DEFINE A NEW BRIGHTNESS VALUE FOR THE PIXEL CURRENTLY AT THE CENTRE OF THE TEMPLATE OR AT ANY OTHER CONVENIENT POSITION. WHEN THIS IS DONE FOR EVERY PIXEL IN THE IMAGE A MODIFIED IMAGE IS PRODUCED THAT ENHANCES OR SMOOTHS GEOMETRIC FEATURES ACCORDING TO THE SPECIFIC NUMBERS

LOADED INTO THE TEMPLATE.

TEMPLATES OF ANY SIZE CAN BE DEFINED AND FOR A M X N PIXEL SIZED TEMPLATE, THE RESPONSE OF THE IMAGE PIXEL (i,j) IS

$$r(i,j) = \sum_{m=1}^{M} \sum_{n=1}^{N} w(m,n) * x(m,n)$$

WHERE x(m,n) IS THE PIXEL BRIGHTNESS VALUE ADDRESSED ACCORDING TO THE TEMPLATE POSITION AND w(m,n) CALLED WEIGHT IS THE TEMPLATE ENTRY AT THAT LOCATION (Fig. A3b & Fig. A3c).

DEPENDING ON THE RELATIVE POSITION OF THE WEIGHTS IN THE TEMPLATES, EACH TEMPLATE GIVES MAXIMUM RESPONSE TO A PATTERN IN CERTAIN DIRECTION WHICH IS TAKEN AS THE **DIRECTION** OF THAT TEMPLATE.

CLASSIFICATION[1][2] : CLASSIFICATION IS A METHOD TO LABEL THE PIXELS IN AN IMAGE AS REPRESENTING PARTICULAR GROUND COVER TYPE OR CLASS SUCH AS WATER, SOIL, VEGETATION etc.,. THE RESULT OF CLASSIFICATION IS CALLED **CLUSTERED IMAGE.**

THRESHOLDING [4] : THRESHOLDING IS THE PROCESS OF REJECTING THE PIXELS WHOSE GRAY LEVELS LIE OUTSIDE THE RANGE OF INTEREST. GRAY LEVEL THRESHOLDING IS USED TO SEGMENT AN IMAGE INTO TWO CLASSES - ONE FOR THOSE PIXELS HAVING VALUES OUTSIDE A SPECIFIED GRAY LEVEL RANGE AND ONE FOR THOSE WITHIN THE RANGE.

UNEQUAL STRETCHING[4] : IT IS THE PROCESS OF MULTIPLYING DIFFERENT GRAY LEVEL RANGES OF AN IMAGE WITH DIFFERENT WEIGHTS TO INCREASE THE CONTRAST BETWEEN FEATURES OF INTEREST AND THEIR IMMEDIATE NEIGHBOURS.

THE METHODS USED IN THIS DISSERTATION WORK TO DETECT LINES ARE:

1. 2 X 2 LINE DETECTING OPERATOR (Fig A4a - Fig A4b)
2. 3 X 3 LINE DETECTING OPERATOR (Fig A5a - Fig A5d)
3. SINGLE PIXEL WIDTH LINE TRACING USING REPONSE AND DIRETCIONS OF LINEAR TEMPLATE OPERATORS ON ORIGINAL IMAGE.
4. SINGLE PIXEL WIDTH LINE TRACING USING CLASSIFIED IMAGE & RESPONSE AND DIRECTIONS OF TEMPLATES ON UNEQUALLY STRETCHED ORIGINAL IMAGE.
5. LINE DETECTION USING ONLY CLASSIFIED OR CLUSTERED IMAGE.

THE METHODS ARE DESCRIBED IN DETAIL IN THE CHAPTER 3.

2 . CLASSIFICATION

CLASSIFICATION IS THE PROCEDURE OFTEN USED FOR QUANTITATIVE ANALYSIS OF REMOTE SENSING DATA. IT RESTS UPON USING SUITABLE ALGORITHMS TO LABEL THE PIXELS IN AN IMAGE AS REPRESENTING PARTICULAR GROUND COVER TYPE OR CLASS[2].

THE IRS IMAGES OF CALCUTTA AND BOMBAY ARE CLASSIFIED INTO SIX CLASES USING MINIMUM DISTANCE CLASSIFIER.

THE NAMES OF THE CLASSES AND THE CORRESPONDING CLASS LABELS ARE GIVEN BELOW [1] :

1. PURE WATER : THIS CLASS CONTAINS POND WATER, FISHERIES etc.,.
2. TURBID WATER : THIS CLASS IS ESSENTIALLY THE WATER WHERE THE SOIL CONTENT IS MORE IN IT.
3. CONCRETE STRUCTURES : THIS CLASS CONTAINS BUILDINGS, RAILWAY LINES, ROADS etc.,. CITY AREAS GENERALLY COME AS CONCRETE STRUCTURES.
4. HABITATION : THIS CLASS BASICALLY CONSISTS SUBURBAN AND RURAL HABITATION. IF A PIXEL HAS A BIG BUILDING AND SOME OPEN AREA IT IS MORE LIKELY TO FALL INTO HABITATION THAN CONCRETE STRUCTURES. THOUGH A CITY AREA IS ALSO A POPULATED AREA, IT IS MORE LIKELY TO BE CLASSIFIED AS CONCRETE STRUCTURES BECAUSE OF THE DENSITY OF BUILDINGS. VILLAGES ALSO FALL INTO THIS CATEGORY.
5. VEGETATION : THIS GIVES ESSENTIALLY THE CROP AREA IN THE SCENE. NOTE THAT, AFTER THE CROP AREA IS HARVESTED THE SAME AREA MAY BECOME OPEN

SPACE (CLASS 6).

6. OPEN SPACES : THIS GIVES BARREN LAND, SAND. AN AREA WITH LESS GREENARY AND WITHOUT ANY CONCRETE STRUCTURES OR HABITATION MAY FALL INTO THIS CLASS.

THE CLASSIFICATION HAS BEEN DONE AS A PART OF THE D.E.A.L, DEHRADUN PROJECT[1].

SINCE THE FEATURES OF INTEREST TO US ARE ROADS, RAILWAY LINES etc., WHICH FALL INTO CONCRETE STRUCTURES AND HABITATION, THE CLASSIFICATION HAS BEEN DONE SUCH THAT **'FEW WATER PIXELS MAY BE CLASSIFIED AS CONCRETE STRUCTURES BUT VERY FEW CONCRETE STRUCTURE PIXELS WILL BE CLASSIFIED AS WATER PIXELS'.**

3 . METHODOLOGY

THIS CHAPTER IS A DESCRIPTION OF THE LINE DETECTING METHODS USED IN THIS WORK.

1. **2 X 2 OPERATOR**[5] : THE TWO ROBERTS' OPERATORS ARE SHOWN IN Fig A4a & Fig A4b. THESE OPERATORS ARE MOVED OVER THE IMAGE ROW BY ROW, COLUMN BY COLUMN AND THE RESPONSES ARE FOUND IN EACH POSITION. THE MAXIMUM OF THE TWO RESPONSES IS ASSIGNED TO THE PIXEL IN THE TOP LEFT HAND CORNER OF THE OPERATOR. THEN THE IMAGE OF RESPONSES IS THRESHOLDED BY FINDING A SUITABLE RANGE OF THRESHOLDS [TH1,TH2] FROM THE HISTOGRAM OF RESPONSES.

2. **3 X 3 OPERATOR**[2] : THE FOUR SOBELS' OPERATORS ARE SHOWN IN Fig A5a THROUGH Fig A5d. THE PROCEDURE IS SIMILAR TO THAT OF 2X2 OPERATOR EXCEPT THAT THE MAXIMUM OF THE FOUR RESPONSES IS ASSIGNED TO THE PIXEL WHICH IS AT THE CENTRE OF THE OPERATOR.

3. **SINGLE PIXEL WIDTH LINE TRACING USING RESPONSE DIRECTIONS OF 3 X 3 OPERATORS ON ORIGINAL IMAGE :** IN THIS METHOD, THE PIXEL AT THE CENTER OF THE OPERATOR IS ASSIGNEED NOT ONLY THE MAXIMUM OF THE RESPONSES OF THE FOUR LINE OPERATORS BUT ALSO THE DIRECTION OF THE CORRESPONDING OPERATOR. AFTER FIXING UP THE THRESHOLD RANGES [TH1,TH2] AND [TH3,TH4], LINE TRACING IS STARTED FROM EACH OF THE POTENTIAL STARTING PIXELS. AT EACH POINT ON THE LINE BEING TRACED THE TRAVERSAL IS DONE IN TWO DIRECTIONS DEPENDING ON THE DIRECTION OF THE PIXEL AT THAT POINT (Fig A6). THE TRACING TERMINATES IF NO NEW PIXEL SATISFYING CERTAIN CONDITIONS CAN BE REACHED FROM ANY POINT ON THE LINE.

THE CONDITION TO BE SATISFIED BY A POTENTIAL STARTING POINT IS THAT, THE RESPONSE OF THE POINT SHOULD LIE IN THE RANGE [TH1,TH2].

THE RESPONSE OF ANY OTHER POINT ON THE LINE SHOULD LIE IN THE RANGE [TH3,TH4].

4. SINGLE PIXEL WIDTH LINE TRACING USING CLASSIFIED IMAGE ALONG WITH THE RESPONSE & DIRECTIONS OF 3 X 3 LINEAR OPERATORS ON THE UNEQUALLY STRETCHED IMAGE :

THE ORIGINAL IMAGE IS CLASSIFIED INTO DIFFERENT CLASSES DEPENDING ON THE GROUND COVER TYPE SUCH THAT EACH PIXEL IN THE IMAGE WILL GET A UNIQUE CLASS.

THE TRACING METHOD IS SIMILAR TO THAT OF 3. ABOVE EXCEPT THAT THERE IS ONE MORE RESTRICTION OF CLASS i.e., THE CLASS OF THE STARTING POINT FOR LINE TRACING MUST LIE IN A SPECIFIED RANGE [CL1,CL2] AND THE CLASS OF ANY OTHER POINT ON THE LINE IN THE RANGE [CL3,CL4].

5. **LINE DETECTION USING CLASSIFICATION :** THIS METHOD USES ONLY CLASSIFIED IMAGE. THE CLASSIFIED IMAGE IS THRESHOLDED SUCH THAT THE PIXELS OUT OF THE RANGE [CL1,CL2] ARE MADE '0' AND PIXELS IN THE RANGE [CL3,C4] ARE MADE '1'. THE RANGE [CL1,CL2] IS THE RANGE OF CLASSES WHICH GIVE LINEAR FEATURES OF INTEREST TO US. TO ELIMINATE NOISE, RESTRICTION ON WIDTH AND LENGTH OF THE LINE SEGMENTS ARE APPLIED.

ALL THESE METHODS RESULT IN DISCONTINUOUS LINE SEGMENTS WHICH NEED TO BE JOINED.

4 . ALGORITHMS

THIS CHAPTER DESCRIBES VARIOUS ALGORITHMS USED TO DETECT LINEAR FEATURES SUCH AS ROADS, RAILWAY LINES etc.,.

ALGORITHM - 1 :- 2 X 2 OPERATOR :

STEP 1. FOR EACH PIXEL P(i,j) IN THE IMAGE DO :

FIND THE RESPONSES OF THE TWO 2 X 2 OPERATORS WITH TOP LEFT HAND POSITION OF THE WINDOW AT (i,j). ASSIGN THE MAXIMUM OF THEM TO THE NEW GRAY LEVEL VALUE OF THE PIXEL P(i,j).

STEP 2. FIND A SUITABLE RANGE OF THRESHOLD [TH1,TH2] USING THE HISTOGRAM OF RESPONSES.

STEP 3. MAKE ALL PIXELS DARK WHOSE RESPONSES LIE OUTSIDE THE RANGE [TH1,TH2] AND OTHERS WHITE OR VICE VERSA.

ALGORITHM - 2 :- 3 X 3 OPERATOR :

STEP 1. FOR EACH PIXEL P(i,j) IN THE IMAGE DO :

FIND THE RESPONSES OF THE FOUR 3 x 3 LINE OPERATORS WITH THE CENTRE OF THE WINDOWS AT (i,j). TAKE MAXIMUM OF THEM AS THE NEW GRAY LEVEL VALUE OF P(i,j).

STEP 2. FIND A RANGE OF THRESHOLD [TH1 , TH2] FROM THE HISTOGRAM OF RESPONSES.

STEP 3. THRESHOLD THE IMAGE TO GET THE LINEAR FEATURES OF INTEREST.

ALGORITHM - 3 :- SINGLE PIXEL WIDTH LINE TRACING USING RESPONSE & DIRECTIONS OF 3 X 3 OPERATORS ON ORIGINAL IMAGE :

STEP 1. LINE DETECTING TEMPLATE CONVOLUTION :

FOR EACH PIXEL P(i,j) IN THE ORIGINAL IMAGE DO:

FIND THE RESPONSES OF THE FOUR 3 x 3 LINEAR

TEMPLATES WITH THE CENTRE AT (i,j). TAKE THE MAXIMUM OF THESE TO BE THE RESPONSE OF THE PIXEL P(i,j). TAKE THE DIRECTION OF THE CORRESPONDING TEMPLATE TO BE THE DIRECTION OF P(i,j).

STEP 2. LINE TRACING :

FIX A THREDHOLD RANGE [TH1,TH2] TO START LINE TRACING AND [TH3,TH4] FOR ANY OTHER POINT ON THE LINE.

STEP 2 a. FOR EACH PIXEL P(i,j) WHOSE RESPONSE LIE IN THE RANGE [TH1,TH2], CALLED STARTING POINT OF A LINE, AND NOT TRAVERSED BEFORE DO :

CALL IT THE CURRENT PIXEL AND DO STEP 2 b.

STEP 2 b. MARK THE CURRENT PIXEL AND FIND THE TWO NEIGHBOURS OF THE CURRENT PIXEL FROM ITS DIRECTION (Fig A6).

STEP 2 c. FOR EACH OF THESE NEIGHBOURS, CALLED OTHER POINTS ON THE LINE DO :

IF THE RESPONSE LIES IN THE RANGE [TH3,TH4]

CALL IT THE CURRENT PIXEL & DO STEP 2 b.

ALGORITHM - 4 :- SINGLE PIXEL WIDTH LINE TRACING USING CLASSIFIED IMAGE ALONG WITH THE RESPONSE & DIRECTION OF 3X3 LINEAR OPERATORS ON UNEQUALLY STRETCHED IMAGE :

STEP 1. UNEQUAL STRETCHING :

UNEQUAL STRETCHING IS DONE TO INCREASE THE CONTRAST OF THE FEATURES OF INTEREST WITH THEIR IMMEDIATE BACKGROUND. IT IS DONE BY MULTIPLYING GRAY LEVELS IN DIFFERENT RANGES WITH DIFFERENT WEIGHTS Fig A7a.

RANGE	WEIGHT
[a,b)	w1
[b,c)	w2
[c,d)	W3

WHERE w1+w2+w3 = 1.

a = MINIMUM GRAY LEVEL IN THE IMAGE.

d = MAXIMUM GRAY LEVEL IN THE IMAGE.

b = MEAN - i * STANDARD DEVIATION

c = MEAN + i * STANDARD DEVIATION

THE MEAN AND SD ARE FOR THE CLASS OF PIXELS THAT ARE OF INTEREST TO US.

STEP 1 a. TO GET CONTRAST ENHANCED IMAGE DO :

FOR EACH PIXEL IN THE ORIGINAL IMAGE DO :

FIND THE RANGE IN WHICH ITS GRAY LEVEL LIES.

IF THE RANGE IS [a,b) THEN MULTIPLY THE GRAY LEVEL BY w1

ELSE IF THE RANGE IS [b,c) THEN MULTIPLY THE GRAY LEVEL BY (w1+w2)

ELSE IF THE RANGE IS [c,d) THEN MULTIPLY WITH (w1+w2+w3).

SEE Fig A7.

STEP 2. LINE DETECTING TEMPLATE CONVOLUTON :

THIS IS SIMILAR TO STEP 1 OF ALGORITHM - 3 EXCEPT THAT THE INPUT IS UNEQUALLY STRETCHED VERSION OF THE ORIGINAL IMAGE.

STEP 3. CLASSIFICATION :

CLASSIFY THE ORIGINAL IMAGE INTO DIFFERENT CLASSES AS DESCRIBED IN CHAPTER 3 . FIX THE RANGE OF CLASSES

[CL1,CL2] TO DECIDE WHERE TO START THE LINE TRACING AND THE RANGE [CL3,CL4] TO DECIDE ANY OTHER POINT ON THE LINE.

STEP 4. LINE TRACING :

THIS STEP IS SIMILAR TO STEP 2 OF ALGORITHM - 3 EXCEPT THAT, THERE IS ONE MORE CONDITION TO BE SATISFIED i.e., THE CLASS OF A STARTING PIXEL MUST BE IN THE RANGE [CL1,CL2] AND THAT OF ANY OTHER POINT ON THE LINE IN THE RANGE [CL3,CL4].

ALGORITHM - 5 :- LINE DETECTION USING CLASSIFICATION :

STEP 1. CLASSIFICATION :

CLASSIFY THE IMAGE DEPENDING ON THE LAND COVER. IDENTIFY THE RANGE OF CLASSES [CL1,CL2] OF THE LINEAR FEATURES OF INTEREST.

STEP 2. THRESHOLDING :

FOR EACH PIXEL IN THE CLASSIFIED OR CLUSTERED IMAGE DO :

IF THE CLASS OF PIXEL SATISFIES THE RANGE [CL1,CL2] MAKE IT WHITE OR '1'

ELSE MAKE IT BLACK OR '0' OR VICE VERSA.

STEP 3. WIDTH LIMITATION ON LINEAR FEATURES :

STEP 3 a. FIX UP THE MAXIMUM WIDTH w1 TO BE ALLOWED FOR ANY LINEAR FEATURE.

STEP 3 b. SCAN THE THRESHOLDED IMAGE OF STEP 2 ROW BY ROW. IF THE LENGTH OF ANY RUN OF 1's IN A ROW IS > w1 MAKE THE RUN BLACK (0) ELSE RETAIN IT.

STEP 3 c. SCAN THE THRESHOLDED IMAGE OF STEP 2 COLUMN

BY COLUMN. IF THE LENGTH OF A RUN OF 1's IN ANY COLUMN > w1 THEN MAKE IT BLACK (0) ELSE RETAIN IT.

STEP 3 d. THE UNION OF THE STEP 2 AND STEP 3 GIVE THE LINEAR FEATURES WHICH ARE OF WIDTH <= w1.

STEP 4. LENGTH LIMITATION OF LINEAR FEATURES :

STEP 4 a. FIX THE MINIMUM LENGTH OF THE LINES ALLOWED 11 IN THE IMAGE.

STEP 4 b. FOR ALL POINTS P(i,j) IN THE IMAGE OBTAINED IN STEP 3 DO :

IF P(i,j) = 1 THEN

CALL IT Q(i,j)

LENGTH = 1

POSITION (LENGTH) = j

DO STEP 4 c.

STEP 4 c. CHECK THE NEIGHBOURS X, Y AND Z (IF EXISTS) OF Q IN THE (i+1) TH ROW. Fig A8.

IF ALL OF THEM ARE 0's THEN

IF LENGTH < 11 MARK THE LINE SO FAR TRAVERSED WITH 2's

ELSE MARK THE LINE WITH 3's

ELSE

PUSH ROW AND COLUMN OF ALL NON ZERO NEIGHBOURS OF Q IN REVERSE ORDER.

REPEAT

POP A ROW AND COLUMN FROM THE STACK AND CALL IT Q(i,j).

VALUE = IMAGE (ROW,COLUMN)

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IF VALUE = 1 THEN
    LENGTH = LENGTH + 1
    POSITION (LENGTH) = COLUMN
    GO TO STEP 4 c
ELSE IF VALUE = 2 THEN
            MARK THE LINE BEING TRAVERSED
            WITH 2's
                ELSE   MARK   THE   LINE   BEING
                TRAVERSED WITH 3's
        UNTIL STACK IS EMPTY.
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AT ANY STEP THE LINE BEING TRAVERSED CAN BE OBTAINED FROM POSITION(1), POSITION(2),.....,POSITION(LENGTH). WHILE MARKING THESE PIXELS WITH 2, SEE THAT THE PIXELS WHICH ARE ALREADY MARKED 3 ARE NOT REMARKED. FINALLY THE LINES OF LENGTH >= 11 WILL BE MARKED 3.

ALGORITHM FOR LINE JOINING :

AN END POINT OF A LINE LINE-1 IS JOINED TO ANY OTHER LINE LINE-2 IFF

1) LENGTH OF LINE-1 >= T1 PIXELS
2) DISTANCE OF LINE-2 FROM THE END POINT OF LINE-1 <= T2 PIXELS.
3) TO FIND THE SLOPE OF LINE-1, T3 PIXELS FROM THE END POINT AND ALONG THE LENGTH OF LINE-1 ARE USED.

SINCE A LINE CAN BE OF DIFFERENT WIDTHS AT DIFFERENT POINTS ALONG ITS LENGTH WE CAN TALK OF LEFT AND RIGHT OR TOP AND BOTTOM ENVELOPES FOR ANY LINE SEGMENT.

STEP 1. FIX UP T1, T2 AND T3.

STEP 2. FOR EACH VERTICAL LINE LINE-1 OF LENGTH >= T1 DO :

FOR EACH END OF THIS LINE DO :

FIND THE END POINTS OF THE TWO ENVELOPES OF LINE-1. CALL THEM Q & P.

FIND THE AVERAGE SLOPE OF THE TWO ENVELOPES FROM T3 PIXELS ALONG ITS LENGTH FROM THAT END. LET THESE TWO SLOPES IN ANGLES BE A_1 AND A_2 (SAY WITH RESPECT TO X-AXIS).

STEP 3. DRAW TWO LINES OF LENGTH T2 EACH FROM Q & P MAKING ANGLES A_1 AND A_2 WITH X-AXIS (Fig A9). FOR EACH OF THESE LINES DO STEP 3 a.

STEP 3 a. IF THE OTHER END OF THE LINE MEET A PIXEL, THEN TAKE THAT PIXEL ALONG WITH ITS LEFT & RIGHT NEIGHBOURS (TOTAL 3). OTHERWISE TAKE ONLY ITS LEFT & RIGHT NEIGHBOURS (TOTAL 2).

STEP 3 b. CALL THEM SETP & SETQ. TAKE THE INTERSECTION OF THESE TWO SETS. IF THERE IS ANY RUN OF 1's IN THIS INTERSECTION THEN DO STEP 4.

STEP 4. FILL THE GAP (ROWS) BETWEEN THE END OF LINE-1 AND THIS RUN OF 1's ROW BY ROW. TO FILL ANY ROW FIND THE INTERSECTION AS IN STEP 3 a (SUBSTITUTE THE WORD END POINT BY ANY POINT ON THE LINE). MAKE THIS INTERSECTION 1's.

STEP 5. REPEAT STEP 2 THROUGH STEP 4 UNTIL NO MORE JOINING IS DONE.

THE PROCEDURE IS SIMILAR FOR HORIZONTAL LINES.

5 . RESULTS

THE RESOLUTION OF IRS IMAGES IS 36.25 X 36.25 sq. mt. THE IRS IMAGES ARE AVAILABLE IN FOUR BANDS. THE BANDS AND THEIR WAVE LENGTHS ARE :

SPECTRAL BAND	WAVE LENGTH RANGE (MICRONS)
BLUE	0.45 - 0.52
GREEN	0.52 - 0.59
RED	0.62 - 0.68
INFRARED	0.77 - 0.86

THE NECESSARY SOFTWARE FOR THE ALGORITHMS HAS BEEN DEVELOPED ON COMTAL PDP - 11 SYSTEM.

THE RESULTS OF THE ALGORITHMS ON THE SATELLITE IMAGES OF CALCUTTA AND BOMBAY ARE PRESENTED IN THIS CHAPTER.

1. **2 X 2 OPERATOR :** THE RANGE OF RESPONSES FOR 2X2 OPERATORS IS LESS. SO FINDING A SUITABLE THRESHOLD IS DIFFICULT. EVEN A CHANGE OF '1' IN THE MAXIMUM OR THE MINIMUM OF THE THRESHOLD RANGE CHANGES THE OUTPUT ABNORMALLY.

THE APPROPRIATE THRESHOLD RANGE FOR CALCUTTA IS [96 - 98 PERCENTILE, MAXIMUM RESPONSE IN THE IMAGE] AND FOR BOMBAY IT IS [93 PERCENTILE, MAXIMUM RESPONSE IN THE IMAGE]. THE RESULT OF THESE THRESHOLD RANGES CONTAIN MOST OF THE LINES IN THE ORIGINAL IMAGE ALONG WITH CLUSTERS OF POINTS.

2. **3 X 3 OPERATOR :** THE RANGE OF RESPONSES OF THESE LINEAR OPERATORS IS HIGH COMPARED TO THE 2X2 OPERATOR, BECAUSE OF WHICH IT IS EASIER TO FIX A SUITABLE THRESHOLD RANGE. FOR THE SAME THRESHOLD RANGES, THE RESULTS OF 3X3 OPERATORS ARE BETTER THAN

THAT OF 2X2 OPERATORS. THE FOLLOWING REASONS CAN BE ATTRIBUTED FOR THIS PHENOMENON.

a. THE NEIGHBOURHOOD OF 3X3 OPERATORS IS MORE THAN THAT OF 2X2 OPERATORS.

b. THE RESPONSES OF BOTH THE 2X2 OPERATORS ARE ABSOLUTELY EQUAL FOR ALL POSITIONS.

3. SINGLE PIXEL WIDTH LINE TRACING USING RESPONSE & DIRECTIONS OF 3 X 3 OPERATORS ON THE ORIGINAL IMAGE : THE THRESHOLD FOR STARTING POINTS IS [99.8 PERCENTILE, MAXIMUM RESPONSE] WHICH GIVES ABOUT 600 STARTING POINTS. THE LINE TRACING HAS BEEN DONE FOR THESE 600 POINTS. THE THRESHOLD FOR OTHER POINTS ON THE LINE IS [90 PERCENTILE, MAXIMUM RESPONSE] (APPROX. 25000 POINTS).

THOUGH THE RESULT OF THE LINE TRACING IS CLEAN, MOST OF THE LINES IN IT ARE NOT CLEARLY VISIBLE IN THE ORIGINAL IMAGE. THIS ALGORITHM IS NOT GIVING GOOD RESULTS.

4. SINGLE PIXEL WIDTH LINE TRACING USING CLASSIFIED IMAGE ALONG WITH THE RESPONSE & DIRECTIONS OF 3 X 3 OPERATORS ON UNEQUALLY STRETCHED IMAGE : THE ORIGINAL IMAGE IN EACH BAND HAS BEEN UNEQUALLY STRETCHED. THE RANGES AND WEIGHTS ARE :

RANGE	WEIGHT
[MINIMUM,MEAN-2*SD)	0.1
[MEAN-2*SD,MEAN+2*SD)	0.8
[MEAN+2*SD,MAXIMUM)	0.1

WHERE **MINIMUM** AND **MAXIMUM** ARE THE MINIMUM AND MAXIMUM IN THAT BAND.

MEAN & **SD** ARE THE MEAN AND STANDARD DEVIATION OF THE CLASS 3 PIXELS IN THE ORIGINAL IMAGE.

THE POTENTIAL STARTING POINTS FOR BOTH CALCUTTA AND BOMBAY ARE FOUND. THE SET OF POTENTIAL STARTING POINTS FOR LINE TRACING ARE THE POINTS FOR WHICH THE CLASS IS EITHER 3 OR 4 AND THE RESPONSE OF 3X3 OPERATORS ON THE UNEQUALLY STRETCHED IMAGE OF EACH OF THE FOUR BANDS IS GREATER THAN OR EQUAL TO THE 3 RD QUARTILE OF THE ORIGINAL IMAGE IN THE SAME BAND.

THE LINE TRACING HAS BEEN DONE FOR THE TOP 50 POTENTIAL STARTING POINTS. THE THRESHOLD RANGE FOR OTHER POINTS ON THE LINE IS [2 ND QUARTILE, MAXIMUM RESPONSE] AND THEIR CLASS IS EITHER 3 OR 4.

MOST OF THE RESULTING LINES ARE MEANINGFUL i.e., THEY ARE ACTUALLY PRESENT IN THE IMAGE. IF THE THRESHOLDS ARE NOT PROPERLY CHOSEN THEN THE RESULTING OUTPUT MAY CONTAIN LINES WITH TOO MANY BRANCHES WHICH ARE NOT CLEARLY VISIBLE IN THE ORIGINAL IMAGE.

5. **LINE DETECTION USING CLASSIFICATION :** THE IMAGES HAVE BEEN CLASSIFIED INTO SIX CLASSES AS DESCRIBED IN CHAPTER 2. UNDER THIS CLASSIFICATION THE LINEAR FEATURES SUCH AS ROADS, RAILWAY TRACKS COME INTO CLASSES 3 AND 4. THE CLUSTERED IMAGE IS THRESHOLDED IN THE RANGE [3, 4].

WITH THE RESOLUTION OF IRS SCANNERS THE ROADS, RAILWAY LINES IN GENERAL ARE LESS THAN OR EQUAL TO 3 PIXELS WIDE. THE PARTS OF LINES IN THE THRESHOLDED IMAGE WHICH ARE MORE THAN 3 PIXELS WIDE HAVE BEEN DROPPED.

THEN THE LENGTH RESTRICTION HAS BEEN APPLIED ON THE RESULT. THE LENGTH RESTRICTION OF 3 & 4 PIXELS GAVE ALL THE LINEAR FEATURES IN THE ORIGINAL IMAGE WITH VERY LITTLE NOISE. THE NOISE IS REMOVED BY JOINING THE LINE SEGMENTS AND APPLYING THE LENGTH RESTRICTION ONCE AGAIN.

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   DIGITAL IMAGE PROCESSING , 1987

LIST OF FIGURES

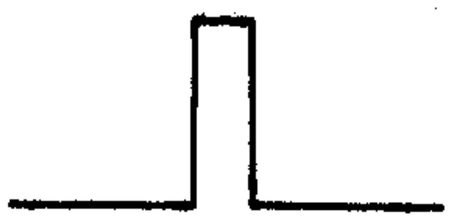

FIG A1a

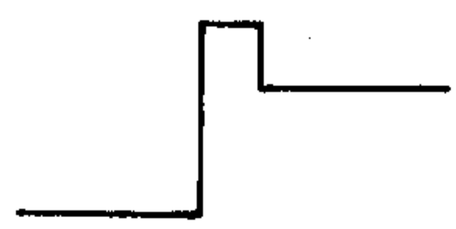

FIG A1b

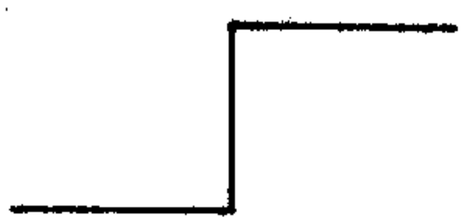

FIG A2a

FIG A2b

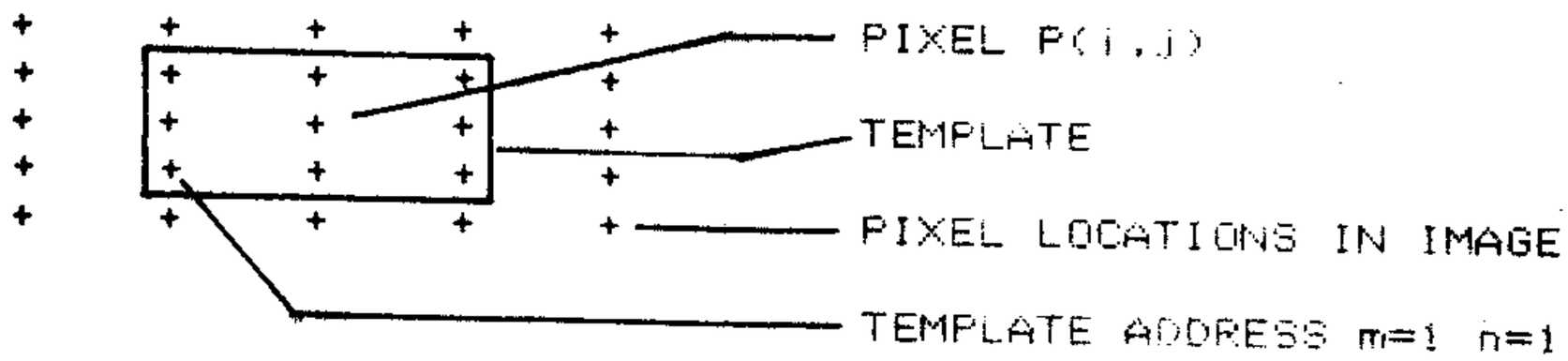

FIG A3a

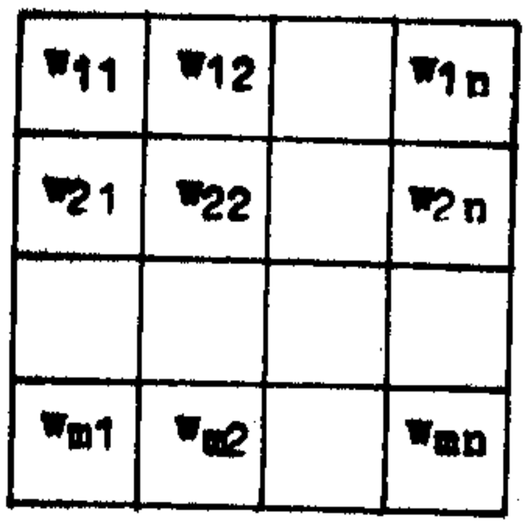

FIG A3b

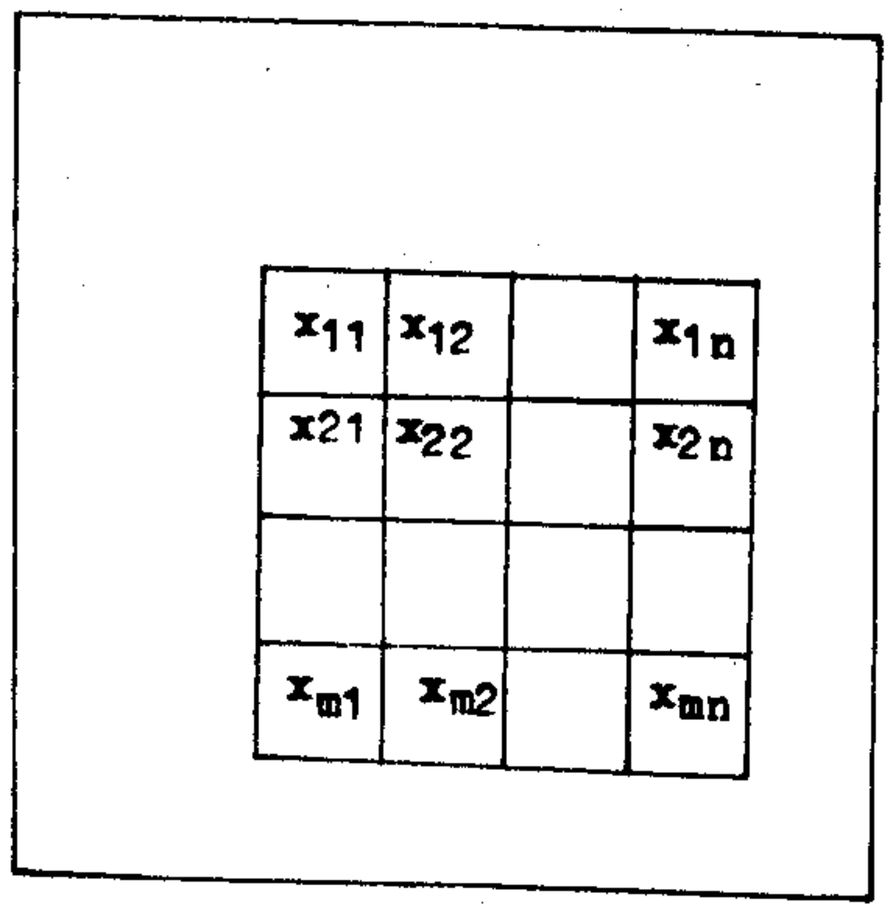

FIG A3c

```
 1    -1
-1     1
```

FIG A4a

```
-1    -1    -1
 2     2     2
-1    -1    -1
```

FIG A5a

DIRECTION = 1

```
-1     2    -1
-1     2    -1
-1     2    -1
```

FIG A5c

DIRECTION = 3

```
-1    -1     2
-1     2    -1
 2    -1    -1
```

FIG A5b

DIRECTION = 2

```
 2    -1    -1
-1     2    -1
-1    -1     2
```

FIG A5d

DIRECTION = 4

```
4    3    2
5    P    1
6    7    8
```

FIG A6

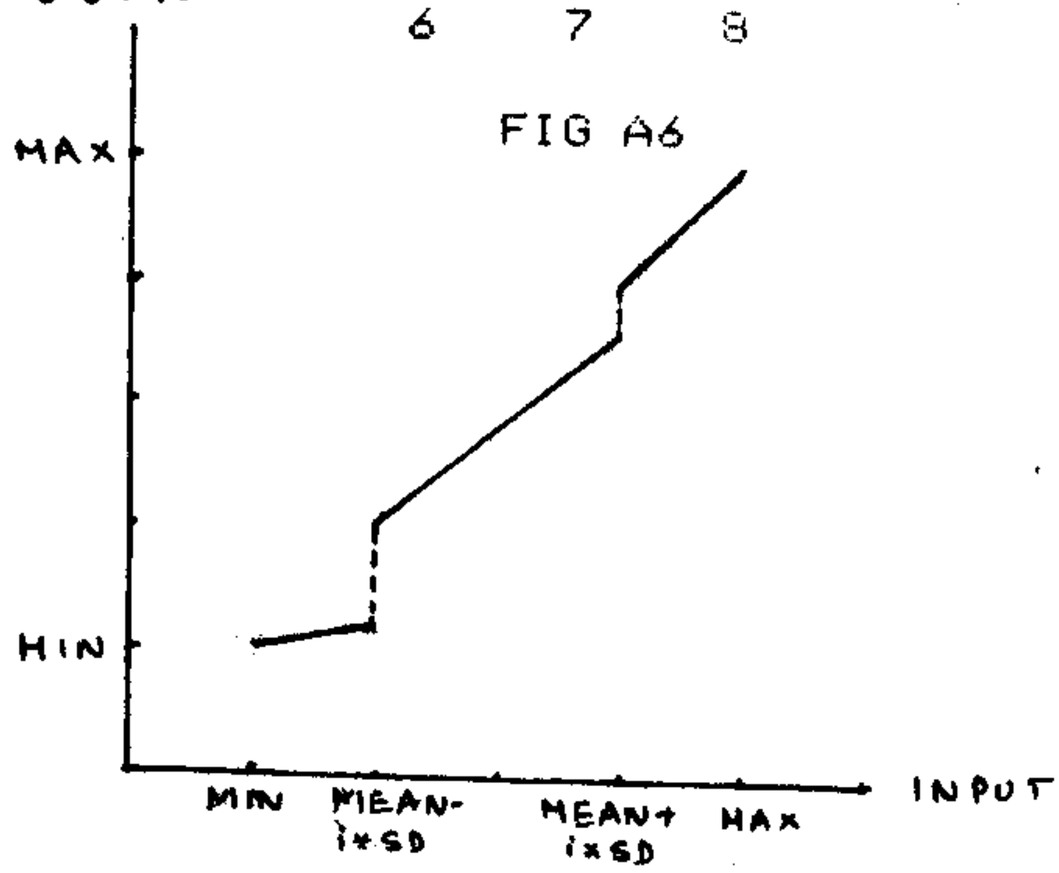

FIG A7

```
j-1     j     j+1   th COLUMN
 ^      ^      ^
 |      |      |
 |      |      |

      Q              -->  i    th ROW
X     Y     Z        -->  i+1  th ROW
```

FIG A8

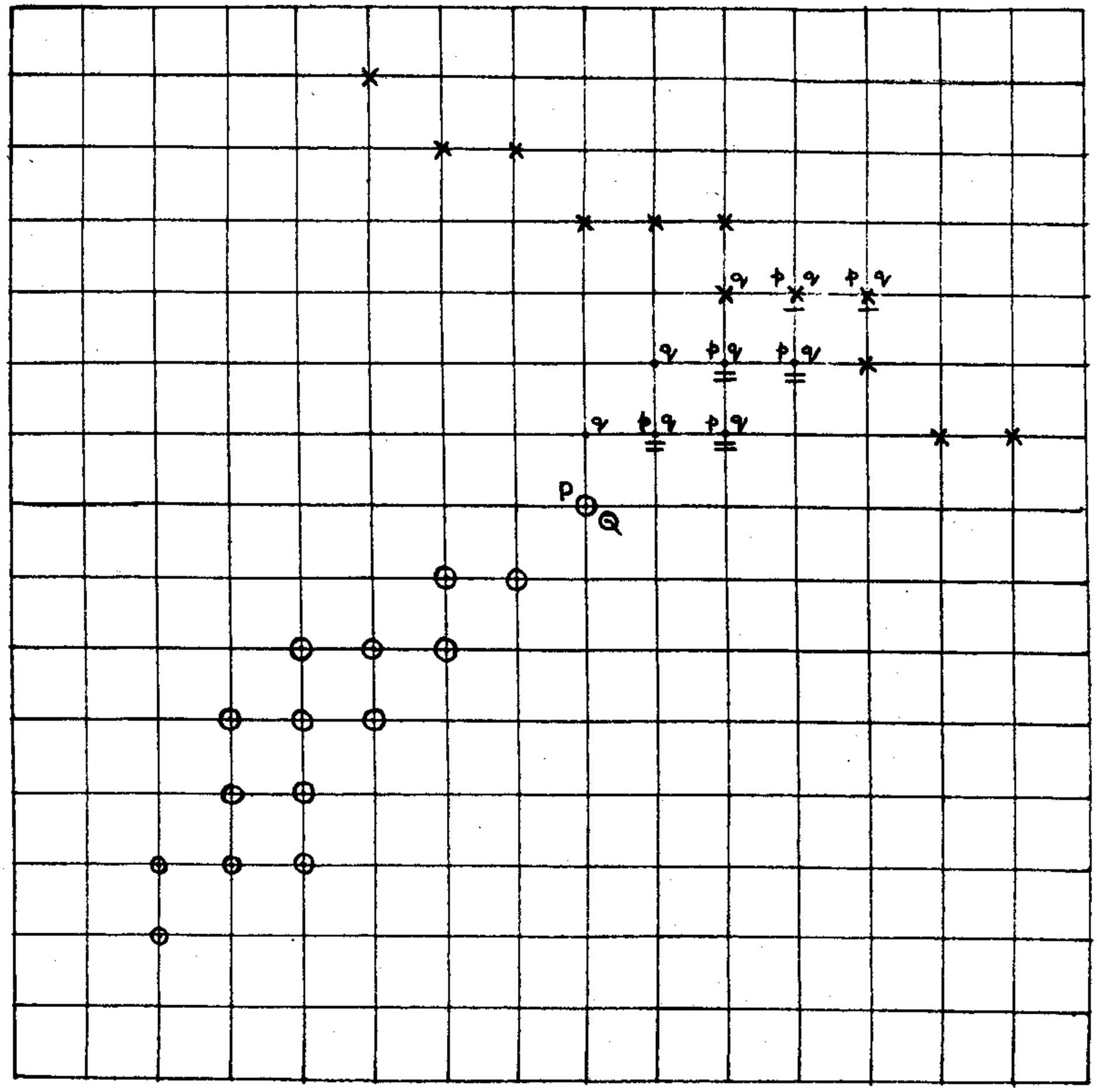

FIG A9

T1 = 6 T2 = 2 T3 = 4
0 - DENOTE LINE-1 X - DENOTE LINE-2
A1 = 35 DEGREES A2 = 45 DEGREES
_ - DENOTE PIXELS TO BE CHECKED FOR THE PRESENCE OF LINE-2
= - DENOTE PIXELS TO BE FILLED UP FOR LINE JOINING