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POTENTIAL SURFACE ANALYSIS: A COMPUTATIONAL METHOD

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ABSTRACT: This paper is on custom programming using FORTRAN for potential surface. The potential surface analysis is a specialised technique and is a derivation of the gravity model. The potential model has applications in social sciences, more especially in geography. The paper presents the algorithm, step by step and explains the nature of computation involved segment by segment and also lists the programme POTSURE in FORTRAN IV. An application is attempted to illustrate the products of analysis.

Introduction

Potential Model has been derived from the Newton's Law of Motion. It states that,

> "Every particle of matter in this universe attracts every other particle with a force which varies directly as the product of the masses and inversely as the square of the distance between them"

According to this Law, any two physical objects in the Universe attract each other with a gravitational force that varies directly with the product of the masses of the objects; the larger they are, the greater is the attractive force. The attractive force or gravitational potential between two objects diminishes as the distance increases (Isard, 1960).

The same principle can be applied to the towns in a continuous surface and a measure of interaction of potential at each town location may be derived. Potential at any point, is a measure of the proximity of that point to all other points in that region, or a measure of aggregate accessibility of the point to all other points in a region. In other words, 'potential' at a point is an aggregate measure of the influence of all distant places for that point.

In a geographically defined region, consisting of n-points, total potential at point 'i' is computed as the sum of the individual potentials created by the existence of every other point including point i. The 'potential' SP created at i by point l is equal to the mass at l divided by its distance from i -

$$SP = \frac{W_1}{di_1} + \frac{W_2}{di_2} + \frac{W_3}{di_3} + \; \ldots \; \frac{W_n}{di_n} \quad .. (1)$$

Where,

SP = the total representation of potential at place i

W_1 = weight of the centre (population, market)

di_1 = the distance between i and l

Thus SP is the total of the effects of all n places on place i including the effects of i itself onto itself.

Methodology

There are two major steps involved, in general, for the calculation of the potential surface. They are,

1. Computation of a distance matrix: There are two ways in which a distance matrix is calculated. One is by using the location of points on the map, the inter-point distances can be calculated from point 1 to the n-number of points manually, using the map scale. This is repeated with the second point to n-number of points and so on. This forms a distance matrix and the diagonal element of the matrix is zero.

The second way is to use the Pythagoras theorem. In this case, the locations are transformed into map co-ordinates. If there are ten locations, there are ten x and y co-ordinates. Using these co-ordinates, the distance between a pair of points can be calculated with the simple Pythagoras formula. For example, the distance between point P2 to point P5 is as follows:

$$D2,5 = \sqrt{(x2 - x5)^2 + (y2 - y5)^2} \quad (2)$$

This is much easier to compute once the main co-ordinate (x and y) are derived from the map (fig - 1).

2. Computation of a Potential Matrix: The next step in the potential surface analysis is the computation of potential matrix using the distance matrix. Potential value of point one is the Weight (the force by which the substance is attracted toward the centre) — in this case population, divided by the respective distance (from the distance matrix). It is repeated for the n-number of points in turn. It should be noted from the distance matrix that the diagonal element is zero (distance between point one to the same point is zero). This diagonal element cannot however be taken as zero because

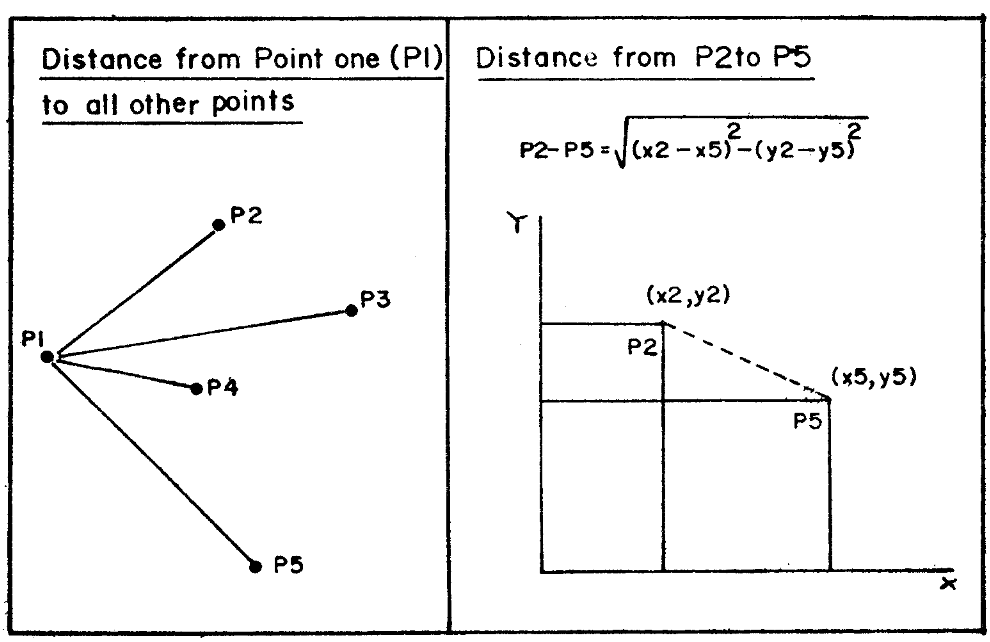


Fig - I

WI/0 would derive SPi to infinity. In such a case therefore the lowest distance in the distance matrix (in the first row) is used as 1 and the same procedure is thus applied for the entire diagonal element in the distance matrix. In the potential matrix, the summation of SPi will give rise to the potential of point one and the process is again repeated for the n-number of points. Then assigning 100% to the largest value in the summative potential matrix, the relative percentage values can be derived for the n-points. These values can be plotted on a map resulting in the construction of the potential surface, with isolines (lines joining places having equal potential value). .

Computational Method

Interaction potential is a general concept which can be applied to Market, population, Migration and Health. When applied to Populations, potential is a measure of nearness of people to one another in the aggregate. It is based on the concept that every individual in a region contributes to the total potential at any place i by an amount reciprocal to his 'distance' away from place i and the measure of population potential is a large scale variable. It measures the relative position of each place with respect to all selected places in the region. In other words, the potential mainly represents an attractive force underlying interaction among places.

As for the computational process is concerned, the smaller the number of points in a region, the smaller will be the time spent in computation. However, while there is a large number of points, the (manual) computation time is extensive and more often the accuracy may be lost. For example, when 50 points are involved, the size of the distance and the potential matrices would be 50x50. Hence, manual computation is painstaking by large

To reduce computing time and to maintain accuracy, a computer algorithm named POTSURF has been developed in FORTRAN. The flowchart in BASIC Language (bit like blue prints and appeal to see events in chart) will explain the different stages of the algorithm in sequential form. (fig–2). The following is the POTSURE algorithm and a detailed explanation has been given, step by step at the end of the programme.

In the first step, the dimensions are: CM(24,3), input data matrix is of the size of 24 x 3, that is, x and y map co-ordinates and the weight (W). DM(24, 25), initially converts a distance matrix taking the x and y co-ordinates and stores in 24 x 24 matrix. From the distance matrix, it picks up the lowest value in each row and writes it in the 25th column. SP (24, 26), using the distance matrix and the weight, computes the potential matrix, where size is 24 x 23. And the summative value is stored at the 25th column and the 26th column represents the potential value in percentages.

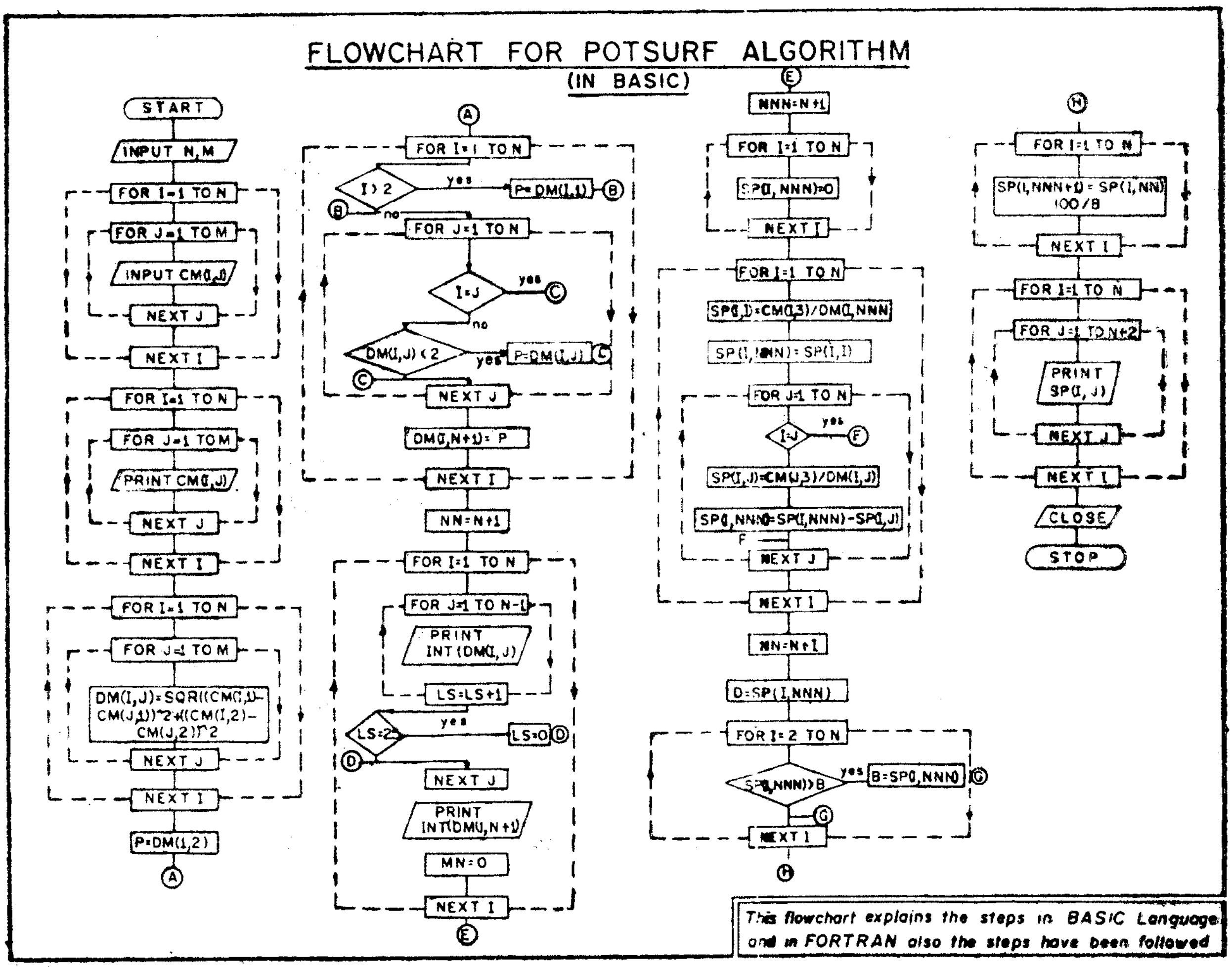
In the second step, the Pythagoras' theorem has been applied to compute distance matrix (as shown above in the second formula). In the third step, the lowest value is selected from each row and the algorithm generates another column to avoid zero in the diagonal element of the distance matrix, to use in the later stage of the potential matrix (in the potential matrix, instead of taking zero value to divide the weight of the point 1), this instinctively picks up the lowest value in place of all the diagonal element.

The final step is the computation of potential matrix and the derivation of potential values in percentages. In this

POTSURF ALGORITHM

```
C       POTSURF ALGORITH TO COMPUTE POTENTIAL SURFACE
        ANALYSIS
C       P. H. Ananthan,
C       Government College for Men, Kumbakonam
C       STEP ONE: DIMENSION & READ STATEMENT
        DIMENSION CM(24, 3), DM( 24, 25), SP(24, 26)
        READ(*, 10)N, M
     10 FORMAT (213)
        READ(1, 20) ((CM(I, J), J = 1, M), I = 1, N)
     20 FORMAT (3F6.2)
C
C       STEP TWO: COMPUTATION OF DISTANCE MATRIX
C       DO 30 I = 1, N
        DO 30 J = 1. N
     30 DM(I, J)=SQRT ((CM(I, 1)-CM(J, 1)**2+(CM(I, 2) -CM(J, 2))
        **2
     40 FORMAT (1x, 24F8.2)
C
C       STEP THREE: SELECTION OF THE LOWEST VALUE FROM THE
C       DISTANCE MATRIX AND FORMS ANOTHER COLUMN
C
        P = DM(1, 2)
        DO 50 I = 1. N
        IF (I.GE.2) P = DM(I, 1)
        DO 60 J = 1, N
        IF (I.EQ.J) GOTO 60
        IF (DM(I, J). LT. F) P=DM (I, J)
     60 CONTINUE
     50 DM(I, J+1) = P
        NN = N + 1
        WRITE(*, 70)((DM(I, J), J = 1, N), I = 1,N)
     70 FORMAT (1X, 25F8.2)
C
C       STEP FOUR: COMPUTATION OF POTENTIAL MATRIX USING
C       DISTANCE MATRIX AND THE WEIGHT
        LL = L + 1                       DO 80 I = 1, N
     80 SP(I, LL) = ) 0.0
        DO 85 I = 1, N
        SP(I, I) = CM(I, 3)/DM(I, LL)
        SP(I. LL) = SP(I, I)
        DO 90 J = 1. N
        IF(I.EQ.J) G0TO 90
        SP(I, J) = CM(J, 3)/DM(I, J)
        SP(I, LL) = SP(I, LL) + SP (I, J)
```

```
 90 CONTINUE
 85 CONTINUE
    NN = N + 1
    B = SP(1, LL)
    L1 - N + 2
    DO 100   I = 2, N
    IF(SP(I,  LL).GT.B)B = SP(I, LL)
100 CONTINUE
    DO 110 I=1,N
110 SP(I,  L1) = SP(I,  LL)*100.0/ B
    NN = N+2
    WRITE(*, 120) ((SP(I, J), J=1, N), I=1, N)
120 FORMAT(1X, 26F8.2)
    END
```



This flowchart explains the steps in BASIC Language and in FORTRAN also the steps have been followed

Fig, 2

AN EXAMPLE OF WORKED OUT PROCEDURE

Table — 1 : Results of the Population Potential Analysis performed for 57 towns (population above 50,000) in Tamil Nadu for 1981 after the POTSURF ALGORITHM

S. No.	Towns	Total Potential	Potential in %
1.	Madras	176,839	100.00
2.	Coimbatore	94,362	53.36
3.	Madurai	95,821	54.19
4.	Tiruchirapalli	92,165	52.12
5.	Salem	79,165	44.77
6.	Tirunelveli	67,854	38.37
7.	Erode	110,544	62.51
8.	Tuticorin	54,667	30.91
9.	Vellore	90,464	51.16
10.	Tiruppur	98,858	55.90
11.	Tranjavur	79,811	45.13
12.	Nagarcoil	43,008	24.32
13.	Dindigul	83,746	47.36
14.	Kanchipuram	107,085	60.56
15.	Kumbakonam	72,396	40.94
16.	Cuddalore	77,970	44.09
17.	Valparai	98,220	55.54
18.	Pollachi	50,330	28.46
19.	Rajapalayam	85,509	48.35
20.	Karaikudi	96,942	54.82
21.	Neyveli	82,867	46.09
22.	Arcot	94,920	53.68
23.	Karur	82,955	46.91
24.	Coonoor	85,247	48.21
25.	Nagapattinam	61,333	34.68
26.	Tiruvannamalai	74,939	42.38

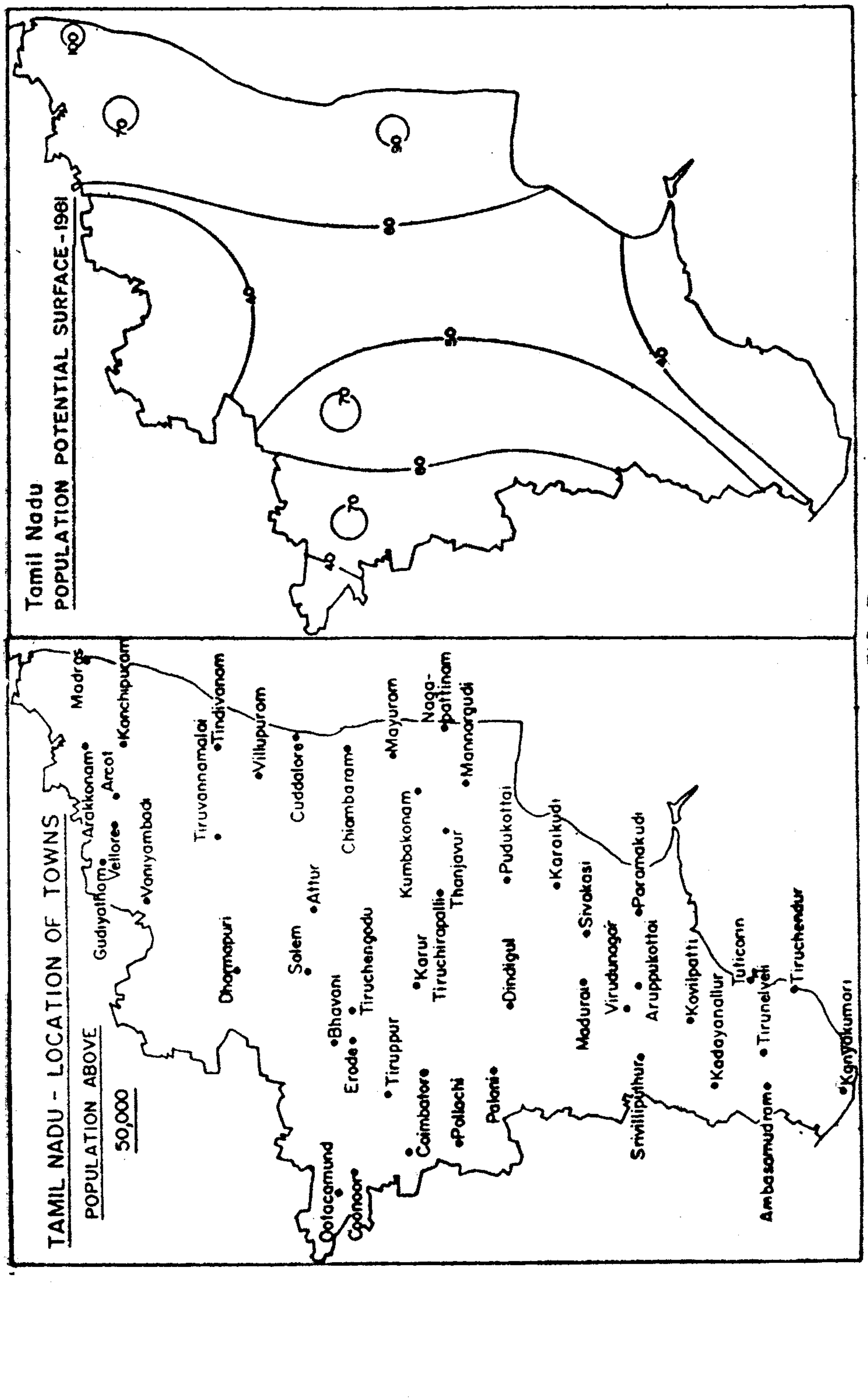

TAMIL NADU - LOCATION OF TOWNS
POPULATION ABOVE
50,000
Madras
Kanchipuram
Arakkonam
Arcot
Vellore
Gudiyatham
Vaniyambadi
Tiruvannamalai
Tindivanam
Villupuram
Cuddalore
Chidambaram
Mayuram
Nagapattinam
Mannargudi
Kumbakonam
Thanjavur
Pudukottai
Karaikudi
Paramakudi
Dharmapuri
Salem
Attur
Bhavani
Tiruchengodu
Erode
Tiruppur
Karur
Tiruchirapalli
Dindigul
Madurai
Sivakasi
Virudunagar
Aruppukottai
Kovilpatti
Tuticorin
Tiruchendur
Tirunelveli
Kadayanallur
Kanyakumari
Ambasamudram
Srivilliputhur
Palani
Pollachi
Coimbatore
Ootacamund
Coonoor
Tamil Nadu
POPULATION POTENTIAL SURFACE - 1961
80
40
50
40

FIG - 3

S. No.	Towns	Total Potential	Potential in %
27.	Pudukottai	91,711	51.86
28.	Sivakasi	77,511	43.83
29.	Gudiyatham	79,901	45.18
30.	Bhavani	108,982	61.63
31.	Ootacamund	58,387	33.02
32.	Villupuram	82,810	46.83
33.	Vaniyambadi	69,370	39.23
34.	Aruppukottai	83,850	47.42
35.	Tiruchendur	49,676	28.09
36.	Palani	93,572	52.91
37.	Virudunagar	87,815	46.66
38.	Mayuram	176,294	99.69
39.	Ambur	75,402	42.64
40.	Kovilpatti	69,270	39.17
41.	Chidambaram	70,583	39.91
42.	Srivill puthur	87,482	49.47
43.	Paramakkudi	69,044	39.04
44.	Kadayanallur	59,683	33.75
45.	Mettupalayam	117,382	66.38
46.	Arakkonam	104,616	59.16
47.	Bodinayakkanur	77,346	43.74
48	Tindivanam	81,658	46.18
49.	Udumalaipettai	79,502	44.96
50.	Tiruchengodu	92,612	52.37
51.	Teni-Allinagaram	78,072	44.15
52.	Ambasamudram	67,071	37.93
53.	Tiruppattur	81,414	46.04
54.	Mannargudi	70,738	40.00
55.	Dharmapuri	69,225	39.15
56.	Attur	76,896	43.48
57.	Kambam	74,306	42.02

stage the potential of point 1 is calculated as shown above in formula 1. It proceeds with the n-number of SP points. If there are 25 points their SP value is stored in the SP(25, 27) with the percenage of potentials. The percntage value is calculated assigning 100% to the highest value in the 27th column, and then based on the highest value the percentage of potentials for all other points will be determined.

From figure-3, the following conclusions are derived: Madras city ranks first among the 75 towns and hence is assigned 100 per cent potential. The second highest value is allotted to Mayuram with the potential of 99.69. Apart from these two other very high potential centres, there are 16 high potential centres also, which contribute betwen 50 to 75 per cent. They are Coimbatore, Madurai, Tiruchirapalli, Erode Vellore, Kanchipuram, Valpara, Karaikudi, Arcot, Pudukottai, Palani, Mettupalawam, Arakonam and Tiruchengodu. The medium potential centres are categorised as those with value between 40 and 50 per cent (23 centres) and 12 centres fall under the category of less than 40 per cent. Some of the towns go even dows to less than 25 per cent of potential (Nagercoil 24.32).

The potential surface (fig-3) indicates that the potential is in general, very high towards the North-east coastal region and decreases towards West, to certain extent (Tiruchirapalli) and again it increases upto 70 per cent (Coimbatore). And there is again a declaining trend towards Western extension because of hilly terrain (Ootacamund), whereas in the North and South directions the centres less than 40 per cent are distributed.

Conclusion

The efficiency of this algorithm is that, it saves time to several hours of manual calculation, if more number of points are involved on a large scale. Secondly, the accuracy of the results. From the above example of the worked out procedure for the Population Potential of Tamil Nadu 1981 (for 57 locations) it is evident that it has taken only less than 40 seconds to compute the distance matrix (57 x 58). This algorithm would be of immense help for the decision makers in geography, marketing, migration, health care systems and so on.

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