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Dot Symbolisation and Its Classification

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Abstract: *Dot is one of the symbols used in the sign system of map graphics and is treated as the most primitive symbolisation forms in thematic cartography. This symbol belongs to the category of point symbols which 'do not belong to the geographical shapes or sizes of the phenomena represented' (Wright,1944[1]). This classification of map symbols is mainly based on the form characteristics of the symbols. These form characteristics are often matched with the mode of occurrence of the spatial data to emphasise the spatial characteristics the referent data. Dot symbols form a subset of the set containing point symbols. The symbol can be described as a dimensionless point symbol, characterising the concept of the spatially discrete magnitudes at point specific locations. The paper attempts to make an effort towards for classifying and analysing the dot symbols as a subset of the set thematic map symbols in terms of their triadic relationship between its three aspects the sign vehicle the designatum or referent and the interpretant. As a sign its relationship with its referent or designatum will also be examined. An attempt will also be made to examine how the signs used in dot symbolisation relate to the referent they represent; and how conceptual variations in structuring these relationships produce differences in dot symbolisation. Two of the components of dot as a sign system i.e. the sign vehicle and the designata; and as a sign its relationship with its referent or designatum will be analysed to define dot symbolisation, and the conceptual variations in such symbolisation. The involved semantic relationships have been cross-classified to form a graphic diagonal identity matrix for showing how the different aspects of designata and possible combinations of means of characterisation lead to different kinds of dot symbolisation; and to different forms of dot maps. The columns in the matrix represent different aspects of the designate and the rows show the different means of characterisation. Five possible combinations at the intersection of rows and columns, suggesting different ways of the structuring of semantic relationships, are located along the column. Each intersection along the diagonal of the matrix, representing an application of the semantic rule, identifies various kinds of dot symbolisation, and resultant forms of dot maps.*

Key Words*:* Dot Symbolisation, Proxy spaces, Triadic relations in symbolisation, Map Graphics, Cartographic Semiotics, Semantic Rule, Classification of dot symbol

I. Introduction

The dot symbol used in the sign system of map graphics is treated as the most primitive symbolisation forms in thematic cartography. This symbol belongs to the category of point symbols which 'do not belong to the geographical shapes or sizes of the phenomena represented' (Wright, 1944[1]). This classification of map symbols is mainly based on the form characteristics of the symbols. These form characteristics are often matched with the mode of occurrence of the spatial data to emphasise the spatial characteristics the referent data. The fundamental logic behind the utility of the symbolisation can be understood in terms of its simple capacity to represent large data magnitudes by a relatively smaller number of dots. The symbolisation is understood to be more affective for visualising comparatively the spatial densities of referent magnitudes as compared to choropleth symbolisation. This symbolisation method allows mapping more than one variable at the same time on the map. Moreover it should be emphasised the no other symbolisation method portrays the detailed features of the distribution of the referent phenomenon which is unlikely to follow the statistical units boundaries. The symbolisation's added advantage is its capability to display the spatial discontinuities in the referent phenomenon.

Frère de Montizon is credited with using dot symbolisation to produce the first map (1830 [2]) of distribution of population of France by departments, where 1 dot was made equal to 10,000 persons. Robinson (1982 [3]) in his book '*Early Thematic Mapping in the History of Cartography*' describes the situation as:

'It is one of the accidents of history that Frère de Montizon's invention of the thematic dot map should have gone completely unnoticed. In terms of cartographic innovations . . . . . it ranks with the isothermal map, yet as far as can be ascertained no reference to him or to his dot map was made by anyone well into the twentieth century…this basically simple, logical idea had to wait some thirty years to be reinvented and much

longer than that to become generally known'

Despite its known characteristics, the symbolisation has neither been investigated in details that it deserves nor has any serious effort been made at a logical classification of this method. The advent of the use of colour in thematic mapping points out this shortcoming more prominently. The single effort that can be cited in this direction is the work of Dahlberg (1967 [4]). The work has touched upon the classification of the symbolisation method and the coverage is limited to almost a large paragraph. He has concentrated more on presenting mapped dot patterns as analogous to a statistical surface and has tried to show that "to relate the dot map to a geographic volume one may regard the dot as a spatial proxy in that it symbolises at a point a quantity known or assumed to occupy geographical space. Although these proxy spaces are not outlined on the map they are implicit from the spacing of the dots on the map." (Dahlberg 1967, p. 159 [4]).

II. Objectives

An attempt will be made here for analysing and classifying the dot symbol as a subset of the set thematic map symbols in terms of their triadic relationship between the three aspects the sign vehicle, the designatum or referent, and the interpretant. As a sign its relationship with its referent or designatum will also be examined. An attempt will also be made to examine how the signs used in dot symbolisation relate to the referent they represent; and how conceptual variations in structuring these relationships produce differences in dot symbolisation. It is expected that such a treatment of dot symbolisation will be of use in efforts at finding appropriate symbolisation solutions in thematic cartography and the associated problems of mapping different sets of point data which have been aggregated over statistical units.

III. Map Graphics

Before proceeding in these efforts it is pertinent to briefly have an overview of map graphics. Map graphics can be regarded a subset of the set containing artificial language of graphics. As an artificial language, it uses a symbolism unique to itself, which in its different manifestations depends on a system of signs. The structural and functional aspects of this symbolism and its associated sign system constitute important stages in map communication and visualisation. These aspects are considered to play a role in map effectiveness (MacEachren 1982 [5]) and thus are a determinant of the efficiency of the system. A formal application of semiotics to these aspects becomes essential for a systematic enquiry into conceptual nature of symbolisation used in map graphics and is basic to understanding of both maps as an information display, along with their communication and visualisation functions.

This is an area in thematic cartography where formal studies are almost nonexistent. The beginning made by Wright (1944 [1]) has not been followed up to the level which it deserves. This state of affairs can be seen as another example of a convention based intuitive approach to map symbolisation and mapping. Dots as a form of such symbolism are not an exception to this. A related attempt in this direction is made to examine how the signs used in dot symbolism relate to the concepts they represent and how conceptual variations in structuring these relationships produce differences in dot symbolisation. The components of sign systems and levels of semiotics involving signs and relations will also be defined towards a classification of signs, in order to provide a formal framework for such an effort.

Morris (1971[6]) has identified the three of the main components of a sign system, which can be identified in case of map graphics too. These components are the 'sign', the 'designaturn' and the 'interpretant'. According to Louis Hébert [7] "the notion of the '*sign'* can be described in several ways. Some definitions are functional: For example, the broadest definition, and one of the oldest, defines the sign as *something that is used in place of something else* (the something else may be interpreted as a signified or a referent". In terms of map graphics, the sign vehicle is the physical manifestation of a selected sign type displayed as an image of a graphic mark. Designatum is that which such a mark or sign denotes, and the 'interpretant' is the shared map message. For the purpose of illustration, an example can be taken from the present context. The non-dimensional mark the 'dot' is the sign vehicle. The designatum is the concept of magnitude of a spatial event, expressed as number of units, at a given location which is defined with reference to its spatial relationships, or in terms of any coordinate system. The interpretant or the shared message is how much of the phenomenon occupies particular locations in the referent space.

3.1 Signs and Thematic Maps Symbols

Since, maps are representations of spatial structures, and such representations operate through the medium of graphic symbolism. Our present concern lies with the signs used in such symbolism: the relationships of these signs with their designata, or the semantic rule. The semantic rule determines the conditions under which a sign is applicable to its designata or referents (Morris, 1971:36 [6]); and the way in which these functional relationships are structured to designate the referents. The symbolisation in this case is based on descriptive rules which provide a greater functional flexibility and wider referent domains for the map symbols

because such relations do not require either a similarity or contiguity between the symbol and the referent.

IV. Dot As Thematic Map Symbol

Dot symbols form a subset of the set containing point symbols. The symbol is supposed to be a dimensionless point symbol, characterising the concept of the spatially discrete magnitudes at point specific locations. Two of the components of dot as a sign system i.e. the sign vehicle and the designata; and as a sign its relationship with its referent or designatum will be analysed to define dot symbolisation, and the conceptual variations in such symbolisation.

4.1 Dot as Sign Vehicle

Dot symbol as a sign vehicle functions through its form. This form is basically defined in terms of its shape. Any shape which alludes itself to a point can be used. However, the shape of the dots, which has the sanction of convention, is ideally described by a perfect circle of a constant diameter. The form variations including the shape are produced by employing graphic variables of surface structure, dimension and colour. Structure of a dot is defined in terms of the surface character of the space enclosed by the perimeter of the dot. The dots can be differentiated by leaving the enclosed area, blank which generates an outline dot or by filling it up to produce an image of a solid dot both achromatic and coloured.

Dimension of the dot is employed as an attribute of shape only (Bowman, 1968: 13[8]) and the dimensional variations are employed to produce shape variations. Dimensions, in case of the dots, are described by the length of its diameter. The dimensional variations in dots are produced by increasing or decreasing the length of the diameter. Dimensions and resultant shape variations are a function of value assignment or scaling of dots. A single value or scale assigned to each dot produces dots of uniform size and, therefore, of uniform shape. If different values or scales are assigned to dots the resultant dots are of different size producing different shapes.

Colour of a dot can be described through basic colour dimensions of hue, value and chroma in Munsell colour notation system (Munsell, 1976;[9] Luke, 1996[10]). Changes in any of these dimensions can produce variations. But the variations of chroma and value are not employed in case of dots as the discrimination of chroma and value becomes difficult with small targets. But the variations of chroma and hue with different hues can be utilised to create differences. The contrast and the resultant discrimination effect of various hues is identified in case of this symbolisation too. These components are the 'sign vehicle', the 'designatum', and the 'interpretant'. In terms of map symbols, the sign vehicle is the physical manifestation of a selected sign type displayed as an image of a graphic mark. Designatum is that which such a mark denotes, and the 'interpretant' is the shared map message.

4.2 The designata

The designata in case of dot symbols comprises of the concept of magnitudes of spatially discrete phenomenon at point specific locations, which are aggregated over an area defined by a spatial unit are collected for individual locations. These values are measured on either interval or ratio scale. In case of agglomeration locational information of the phenomena is not collected, but is considered inherent to it. Examples of such concepts of magnitude can be found in number of inhabitants, number of villages, acreage of a certain crop or population of milch animals etc.

Designata or referent data, in the present case, has some other aspects too. These aspects are manifested when attribute based nominal or ordinal categories, forming component parts of the whole, are identified. Magnitudes are reckoned separately for each of these categories which have their ascribed point specific locations.

One such aspect becomes evident in case of the partitioning of the phenomenon and its ascribed locations into attribute based dichotomous categories when such an attribute is measured on nominal scale. Examples of such partitioning are economically active population subdivided into primary and non-primary sectors of economic activity, division of population on the basis of sex, categorisation of urban land use area into residential and non-residential area. Such divisions are also made in binary mode when the classificatory criteria is presence or absence of an attribute, such as identification of villages in two categories of electrified villages, and non-electrified villages; division of houses in a settlement on the basis of presence or absence of certain amenities; or employment status of population categorised into workers and non-workers.

A different aspect of the designata is identified, when the referent phenomenon and its locations are differentiated, in terms of, some attribute, and are subdivided. Such subdivision classifies the referent phenomenon, and its location into manifold component categories, or using the language of set theory, the set containing a referent phenomenon and its ascribed locations as elements is partitioned into subsets, using any attribute as the defining properly. Examples of such classification are seen when acreage of land under farming is subdivided into acreage under different framing types, economically active population is

subdivided into occupational categories, or acreage of cultivated land is differentiated in terms of acreage under different crops.

Another aspect of designata becomes apparent when size is used as an attribute for stratification of location of phenomenon into classes measured on ordinal scale. Examples of such stratification can be found in case of ordered categories of size of rural settlements. Cultivated areas classified by size of agricultural holdings, households classified into size categories of its members. A variant of size related differentiation is seen when magnitudes of phenomenon are generalised by agglomeration in different size classes (Ratajski, 1967: 149 [11]). Still another aspect of the designata is manifested when the phenomenon and its locations are stratified into manifold nominal categories on any attribute based criteria, and magnitudes in each such category of phenomenon are generalised by agglomeration into different size classes. The nominal classificatory operations take into account the locations of phenomenon, but generalisation manipulations are restricted to magnitudes only without any consideration for the attribute of location.

4.3 Semantic Relations

The semantic relation of characterisation between the dots as thematic map symbols and the referent magnitudes takes the form of a descriptive rule based relationship. The relationships between dot symbols and their designata are basically structured in a way in which the dots signify both locations and magnitudes of a phenomenon in referent space. These symbols operate through their number of occurrences, which results in place to place variations in symbol density, characterising the spatial variations in magnitudes as well the configurations of locational patterns of such magnitudes. The characterisation of the magnitudes involves the use of a measurement form different from the form of the designatum. The one-dimensional quantities measured in terms of a fixed scale are translated into a number of plan forms of dots. Basically these relations take the form in which '*m*' is the magnitude of any phenomena in any statistical unit '*i*' and '*N*' are the numbers of dots at that location. The numbers of dots are obtained by scaling the magnitude of the referents '*m*' in any areal unit by the dot value '*x*' as:

$$N = m_{i\,/\,x} \qquad (1)$$

Where *'x'* is the selected value of referent magnitude called dot value for a given size of a unit dot of a given or selected size of dot.

Both dot size and dot values are obtained iteratively and sometimes by graphic devices in the form of nomographs (Mackay, 1949[12]). The information losses in the process of converting magnitudes into number of dots which take the form of remainders are taken as a natural consequence of graphic transformation and are not taken into account and ignored. The relative spatial variations in magnitude or logico-mathematical relations are effectively preserved when scaling dots so that their numbers '*N*' are equal to the referent magnitudes 'm_i' because the scaling transformation maintains these relative differences as shown above in (1) above.

However, the different aspects of designata in terms of attribute based categories, and size stratification require differences in application of semantic rule, or a different mode of structuring of semantic relations. These are achieved by symbol form variations produced by differentiation of surface structure, colour, size and the resultant shape. Differences in structuring of semantic relationships lead to the conceptual variations in dot symbolisation and to different forms of dot maps. These variations in structuring the semantic relations can be used to classify dot symbolisation. Formal studies in this area are almost nonexistent.

The types of involved semantic relationships can be cross-classified to form a graphic diagonal identity matrix for showing how the different aspects of designata and possible combinations of means of characterisation lead to different kinds of dot symbolisation; and to different forms of dot maps (Figure 1). The columns in the matrix represent different aspects of the designate and the rows show the different means of characterisation.

Five possible combinations at the intersection of rows and columns, suggesting different ways of the structuring of semantic relationships, are located along the column. Each intersection along the diagonal of the matrix, representing an application of the semantic rule, identifies various kinds of dot symbolisation, and resultant forms of dot maps. They are discussed separately in the following part of this section.

1. The first column showing an aspect of the designatum in which magnitudes of a phenomenon are located at point specific positions, and its intersection with the first row which identifies repetition of uniform symbols as means of characterisation, specifies one kind of semantic relationship. Structuring of this relationship produces a symbol pattern in which the uniform symbol shape is used to signify the point specific locations of magnitude, while the repeated occurrences of symbols at such locations, producing a visual impression of varying density, is employed to characterise the spatial variations in the distribution of the phenomenon. Discrete positional representation of magnitudes produces pattern configurations, which characterise spatial arrangement of patterns, zones of transition, and the lines of sharp breaks in the distribution of such phenomenon in the referent space. The nature of designatum and the means of characterisation require the use of uniform symbols in terms of shape and scale. Since, referent locations are not differentiated in any

way, a uniform surface structure is used. The symbol type may be described as 'uniform monochrome single scale dots' referred as 'single scale dots' in common usage. The symbol use generates an image in the fashion of

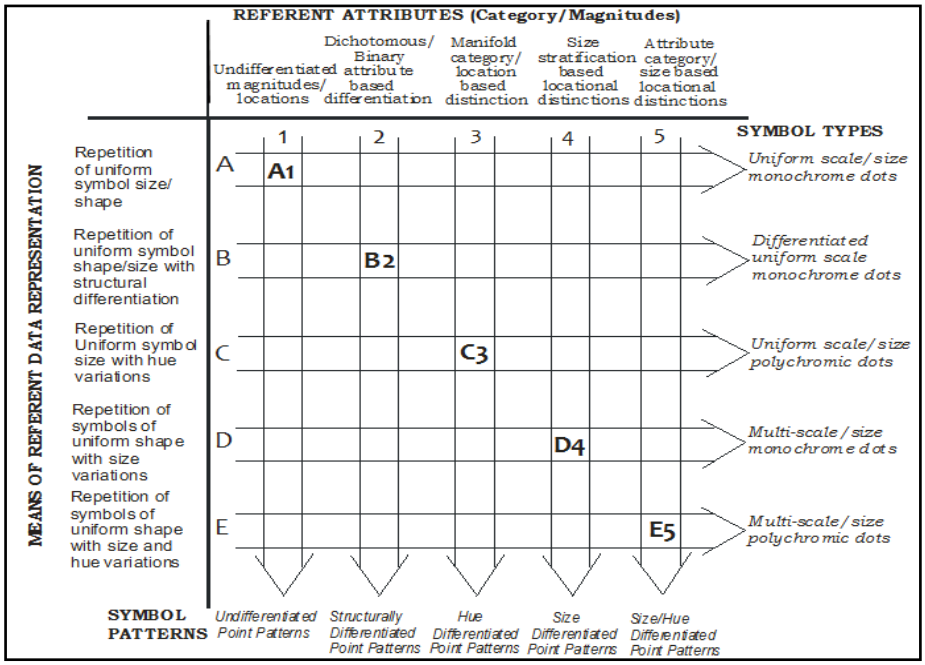

Figure 1: Identity matrix for classification of types of dot symbolisation

undifferentiated point patterns. The intersection A1 defines a map form which can be termed as 'single scale dot map'. Examples of symbolisation can be seen in Smith (1920[13]) in case of rural population, and in Marschner (1950[14) including several other published works.

Figure 2: Dot Maps Symbolised with uniform (undifferentiated) size/shape achromatic symbols

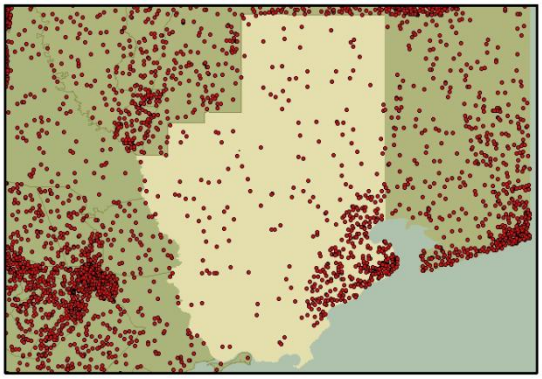

Figure 2 A. Dot Maps Symbolised with uniform (undifferentiated) size/shape monochromatic symbols (Source not available)

2. The second column and the second row of the matrix identify, respectively, an aspect of the

designatum where the magnitudes of a phenomenon at point specific locations are partitioned into attribute based categories, which are either dichotomous or in binary mode; and a means of characterisation which uses structure differentiated dot symbols. This intersection of row and column represents an application of the semantic rule, where the separate identity of the two categories, or the presence and absence of an attribute is characterised by a surface-structure produced form differentiation in dot. Varying density of two different symbol forms, generated by dot recurrence at respective locations of each category, characterises the variations in spatial distribution, as well as the relative spatial concentrations. Point specific representation of magnitudes of each category, in map space; produce varying pattern configurations which characterise spatial variations of interrelationships in categories of referent phenomenon. The outline dot, which alludes to an impression of emptiness, adequately characterises the absence of an attribute in binary mode of classification. Since the aspect of referents and the means of characterisation require a differentiation in kind only, no other graphic variable, except surface structure, is used to produce the desired effect. The symbol, type may be designated as 'structure differentiated, single scale monochrome dots' producing an image of differentiated dot pattern. The map form identified at the intersection B_2 may be described as 'structure differentiated single scale monochrome dot map.

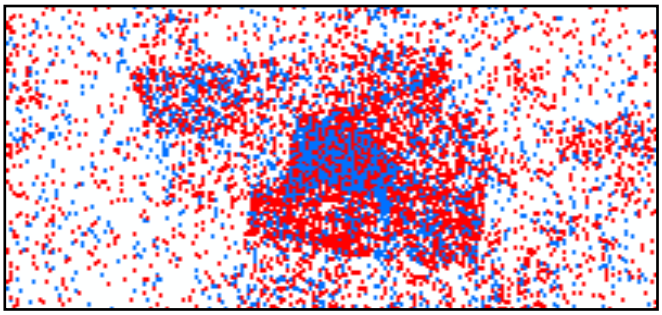

Figure 3. Dot Maps dichotomous distributions by hue differentiated uniform size symbols. Red dots represent Republican votes and Blue dots represent Democrat votes. (Portion of Map of 2012 US Presidential Voting Patterns by County: Democrats and Republicans *http://carto.maps.arcgis.co* [15]

3. The third intersection is formed by the column designating as aspect of the referent in which positional magnitudes of a phenomenon are subdivided into manifold component categories, and the row showing a means of characterisation in which recurrent polychrome uniform symbols are used. The intersection denotes a way of structuring the semantic relationship in which different/separate colour dots are used for characterising the component categories (Figure 3). The repeated occurrence of dots of different hues, at their respective point locations produces patterns of varying symbol density characterising the variations in the distribution, in terms of spatial dominance of one or more categories while the composition of dots of various hues in a pattern characterises the different combinations of the categories in the referent space.

The designatum aspect and means of characterisation exclude the possibility of any other variation in symbol from except hue and require uniformity in shape and scale. The symbol type, which is employed in such situation, may be described as single scale polychrome dots. The symbol use leads to the generation of a pattern image which can be designated as 'colour differentiated point pattern', and the associated map form identified at the intersection C, may be named as 'polychrome single-scale dot map'.

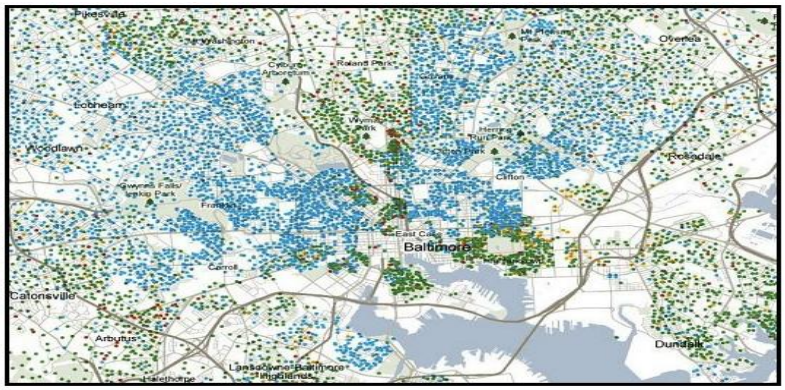

Figure 4. Dot map of hue differentiated uniform sized sybols (Portion of map from Better Census Maps with Dot-density *thewhyaxis.info/**census***/ [16]

4. The fourth column in the matrix represents a referent aspect in which the referent magnitude at their locations are stratified into size classes, while the corresponding row identifies repetition of symbols of variable shape as means of characterisation or representation. The different size classes, of referent phenomenon, are characterised by different dot shapes produced by dimensional variations. The repeated occurrence of multi-shape dots at their respective point specific location, producing variable symbol density patterns, characterise not only the spatial variations in the distribution, but also the spatial organisation of size hierarchy of location in the referent space. In case of the other variant of this aspect of the referent content

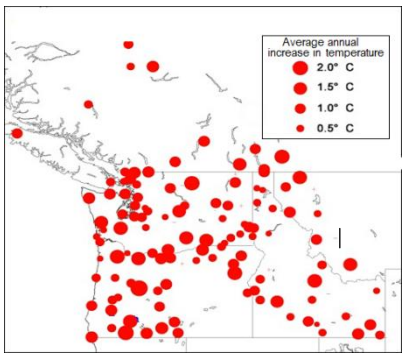

Figure 5. Dot map of size differentiated symbols (from Climate Impacts Group's (CIG) map of increases 20th century trends in average annual temperature 1920-2000 [17]

in which magnitudes are generalised by agglomeration into different size classes and patterns produced by recurrence of multi-shape dot symbols characterise relative regional concentrations, and zones of transition in the distribution of referent phenomenon (Figure 5). The means of characterisation requires dimension dependent shape differentiation in dot symbols produced by the scale variation. Since the designatum is not differentiated, in any other way, a uniform surface structure is used in this case too. The resultant symbol type may be described as 'multi-scale monochrome dots' which produces 'size stratified point patterns'. The map form obtained at intersection D. with the use of this kind of symbolisation can be termed as 'multi-scale monochrome dot map'. Such applications are exemplified in maps of Gilman (1936[18]) and Porter (1966[19]).

5. The fifth such combination is located at the intersection of the last column and row. The column identifies a designatum aspect in which the positional magnitudes are first classified into attribute magnitude based manifold categories, and then the magnitudes of each category are generalised by aggregation into size

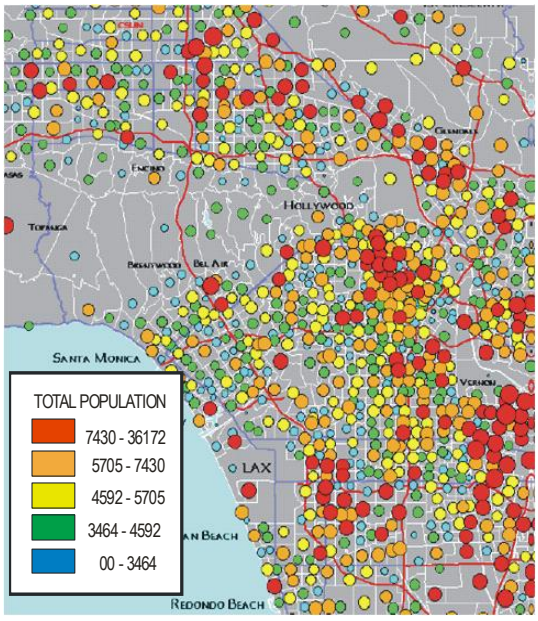

Figure 6. An Example of Dot Map of (Portion of 'Map of Population Distribution of Los Angeles County' from Bowen W. 1996,*www.prolades.com/glama/lacoeth.htm* [20])

classes or magnitude locations are stratified into size classes. The row describes the use of recurrent multi-colour and multi-shape (size produced) symbols as means of characterisation. Structuring of semantic relation takes a form in which density patterns of the symbols of different colours, characterise the relative dominance of categories and their combinations in referent space. The patterns produced by the varying organisation of multi-shape dot of different colour characterise or represent relative concentrations in the distribution of different categories, locations of zones of transition and relative dominance, of one, or more categories in at various referent category combinations (Figure 6). The means of characterisation, and the aspects of the referent define a symbolisation category in which at the first stage, hue is employed to achieve form differentiation, and at the second stage, dimension dependent shape is used to produce form variations in dots of each colour. The symbol type may be named as 'multi-scale polychrome dots. The patterns produced by these symbols and the resultant may form may be described as 'size stratified colour differentiated dot patterns' and 'polychrome multi-scale dot maps, respectively. The population and other sheets published by NATMO are one of the examples of application of such symbolisation. (Chatterji, 1959 [21]; Das Gupta, 1976 [22])

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