

SYMBOL-BASED SIMPLIFICATION WITH FUZZY LOGIC APPROACH ON MOBILE DEVICES

O. Akcay *, O. Altan

ITU, Faculty of Civil Engineering Faculty, Division of Photogrammetry 34469 Maslak Istanbul, Turkey - (akcayoz, oaltan)@itu.edu.tr

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ABSTRACT:

Recent developments of GSM technology enable new applications in distributed GIS and LBS so as to provide more relevant active service to the mobile user. Specifically, the visualization of the spatial data is very important for mobile devices that have limited display capacity. The visualization problems are mostly dealt with generalization algorithms such as displacement, simplification and aggregation in order to obtain appropriate cartographic design. In this paper, a new simplification method that allows an adapted visualization is proposed. According to the proposed model, instead of scaled polygonal spatial representation, symbolizations are used for the visualization. In theory, a spatial object is replaced with a symbol in order to make user's perception easier in the restricted screen of the mobile devices. Obtaining an appropriate icon size for a spatial object is very complex case because of the various parameters of the determination of the symbolization. Besides, there is also a vagueness of the situation in the visualization. Solution, therefore, needs a fuzzy logic approach so as to obtain coherent results. Symbol dimensions are calculated automatically with fuzzy inference depending on both the display resolution and the covered area of the polygon. A technological architecture of the distributed GIS has been designed to realize cartographic generalization on the mobile phones. Finally, adaption has been provided for the each spatial object separately according to the display resolution capacity of the mobile device and the size of the spatial object.

1. INTRODUCTION

In cartography, relevancy means relation between the user and the visualisation. Visualisation of spatial objects can be handled from different points of view. One of these research efforts is "generalisation". Generalisation is needed in order to represent relevant information at an appropriate level of detail. Generalisation includes different algorithms such as simplification and displacement to determine an optimal shape of the spatial objects for any scale. Many scientists have developed mathematical models of simplification and displacement for generalisation (Nickerson, 1988; Ruas, 1998; Lamy et al., 1999). Sester (2000) and (2005) explained generalisation models based on least squares adjustment (Figure 3.1). Although the developed generalisation algorithms are efficient enough for desktop systems, mobile systems require simpler visualisation algorithms and approaches to provide maps for mobile devices, because of the limited computation and display capacity of the devices.

Edwardes et al. (2005) proposed an approach based on the notion of hierarchical spatial tessellation for generalisation. They used the quadtree to make decisions on the number of objects to display. The quadtree tessellates space until every point is assigned to a separate block. While zooming happens a level is chosen that meets a minimum acceptable symbol size criterion. In particular the solution allows rapid traversal and retrieval of data for LBS. The research stresses the importance of the symbol size in LBS so as to represent data appropriately.

To use small screens of mobile phones and PDAs more effectively, symbol-based simplification is proposed as a complementary algorithm of the semantic approach, a computing algorithm that benefits semantic models by increasing the ability of the model to provide appropriate relevant visualisation for the context in addition to semantic reasoning. According to the proposed model, instead of scaled polygonal spatial representation, symbolisations are used for visualisation. In theory, a spatial object is replaced with a symbol that can be in a different form such as a square or circle in order to make the user's perception easier in the restricted screen of the mobile devices. The model provides a simplification method for the limited mobile devices instead of developed generalisation methods that have been proposed for desktop applications by Lamy et al. (1999), Sester (2000) and Sester (2005).

The model determines new symbol size depending on area of the object and the pixel size of the screen of the user's mobile device. For instance, Figure 1 shows three spatial objects on the left (picture A) and three rectangle symbols replace them on the right (picture B). Different screen sizes and different objects require a unique symbol size to represent spatial objects properly.

To categorise icon size is very complex because of the various parameters of the determination of the symbolisation. There is also a vagueness of the situation in the visualisation. The solution needs a fuzzy logic approach for coherent results. Edwardes et al. (2005) also use adaptive symbols in a different method, as explained before, in order to represent data.

* Corresponding author.

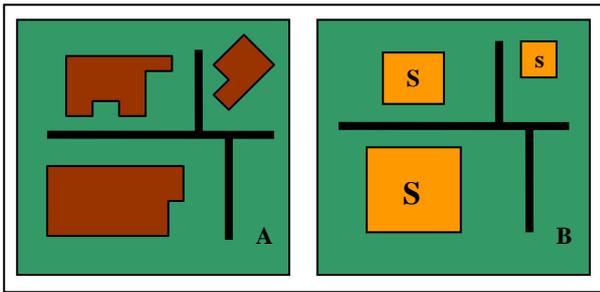


Figure 1. Picture A is the original map, picture B is the symbol-based map

2. SYMBOL-BASED SIMPLIFICATION

Map scale and the area of a polygonal object are two parameters for determining a new symbol size for the visualisation of any object. Let us suppose that different spatial objects will be represented with a symbol on the map under a certain scale. Symbols that have the same size can cause representation problems because each object has a different size on the map. For example, a symbol size might be too small to represent a large spatial object or might be too large to represent a small spatial object. The aim of the model should be to provide appropriate symbol sizes for different spatial objects according to their original sizes. The second parameter is the map scale to define a convenient symbol size. A symbol size can be too large for a small-scale map or it can be too small for a large-scale map. Map scale is calculated as follows (Equation 1).

Actual average pixel size can be accepted as 0.28mm per pixel in Equation 1. Actual dimensions of the display area are determined as 250m. X 250m. Pixel dimension value of the display is therefore only parameter for the scale, since actual pixel size and actual dimension of the display are the constant values in Equation 2.

$$S = \frac{PD \times AS(m)}{AD(m)} \quad (1)$$

$$S = \frac{PD \times 0.00028(m)}{250(m)} \quad (2)$$

where S = scale
 PD = pixel dimension value of display
 AS = actual size of per pixel
 AD = actual dimension of display

The area of the spatial object and the display resolution of the mobile device (the pixel dimension value of the display) are defined as two subjects of the membership functions. Fuzzy sets in the solution are based on Zadeh (1965). Four IF-THEN rules (two-input, one-output fuzzy reasoning rules) are expressed as

- IF area is large AND resolution is high THEN pixel size is 40.
- IF area is large AND resolution is low THEN pixel size is 17.
- IF area is small AND resolution is low THEN pixel size is 14.
- IF area is small AND resolution is high THEN pixel size is 25.

2.1 Membership Functions

The consequential values of four premises enumerated above have been determined with the trial and error method until the desired results have been obtained for each premise. Memberships function for large spatial objects in Equation 3:

$$\mu_{A-Large}(x) = \begin{cases} 0 & x < 360m^2 \\ \frac{x-360}{11000-360} & 360m^2 < x < 11000m^2 \\ 1 & x > 11000m^2 \end{cases} \quad (3)$$

Memberships function for small spatial objects in Equation 4:

$$\mu_{A-Small}(x) = \begin{cases} 1 & x < 360m^2 \\ \frac{11000-x}{11000-360} & 360m^2 < x < 11000m^2 \\ 0 & x > 11000m^2 \end{cases} \quad (4)$$

Memberships function for high display resolution in Equation 5:

$$\mu_{B-High}(y) = \begin{cases} 0 & y < 130 \text{ Pixel} \\ \frac{y-130}{350-130} & 130 < y < 350 \text{ Pixel} \\ 1 & y > 350 \text{ Pixel} \end{cases} \quad (5)$$

Memberships function for low display resolution in Equation 6:

$$\mu_{B-Low}(y) = \begin{cases} 1 & y < 130 \text{ Pixel} \\ \frac{350-y}{350-130} & 130 < y < 350 \text{ Pixel} \\ 0 & y > 350 \text{ Pixel} \end{cases} \quad (6)$$

Figure 2 shows membership functions explained in Equations 3 and 4, whereas Figure 3 shows membership functions given in Equations 5 and 6.

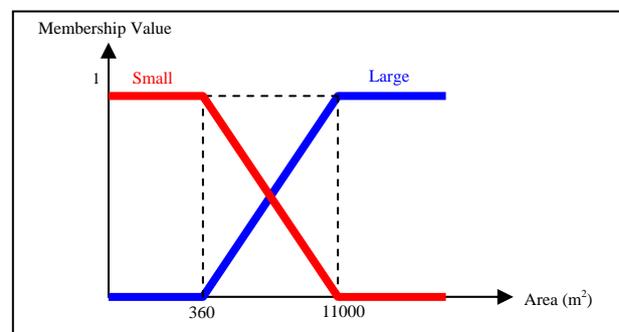


Figure 2. Membership functions for large and small spatial objects

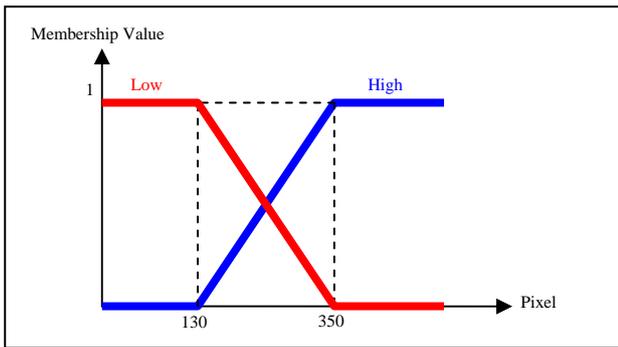


Figure 3. Membership functions for high and low display resolutions

2.2 Fuzzy Reasoning

Let us assume that x_0 and y_0 are the input values for the premise variables. Equations 7, 8, 9 and 10 apply the input values to the premise variable and compute the minimums of membership functions:

$$Rule_1 : m_1 = \min(\mu_{A-Large}(x_0), \mu_{B-High}(y_0)) \quad (7)$$

$$Rule_2 : m_2 = \min(\mu_{A-Large}(x_0), \mu_{B-Low}(y_0)) \quad (8)$$

$$Rule_3 : m_3 = \min(\mu_{A-Small}(x_0), \mu_{B-Low}(y_0)) \quad (9)$$

$$Rule_4 : m_4 = \min(\mu_{A-Small}(x_0), \mu_{B-High}(y_0)) \quad (10)$$

Equations 11, 12, 13 and 14 are conclusion values of all rules:

$$Conclusion_1 : c_1' = m_1 c_1 \quad (11)$$

$$Conclusion_2 : c_2' = m_2 c_2 \quad (12)$$

$$Conclusion_3 : c_3' = m_3 c_3 \quad (13)$$

$$Conclusion_4 : c_4' = m_4 c_4 \quad (14)$$

Final conclusion is obtained as in Equation 15:

$$c' = \frac{\sum_{i=1}^4 c_i'}{\sum_{i=1}^4 m_i} \quad (15)$$

3. THE DEFINITION OF THE SYMBOL SIZE

As explained in section 2, symbol-based simplification is applied to the visualisation in order to obtain more uncomplicated map outputs on small screens. The symbol-based simplification can be applied as follows:

Let us suppose there is a spatial object that is 950 m² and the mobile device has 320 X 320 pixels capacity to show that spatial object. The spatial object represents a medical unit in the Campus of ITU. In Figures 5 and 6, the spatial object is symbolised with a capital H letter with black colour in a circle filled with white colour. The membership values for the pixel size of the display of the device and the area of the spatial object are calculated from membership functions in equations 3, 4, 5 and 6:

$$\mu_{A-Large}(x) = 0.06 \quad (16)$$

$$\mu_{A-Small}(x) = 0.94 \quad (17)$$

$$\mu_{B-High}(y) = 0.86 \quad (18)$$

$$\mu_{B-Low}(y) = 0.14 \quad (19)$$

The minimums of the memberships function values:

$$Rule_1 : m_1 = \min(\mu_{A-Large}(x_0), \mu_{B-High}(y_0)) = 0.06 \quad (20)$$

$$Rule_2 : m_2 = \min(\mu_{A-Large}(x_0), \mu_{B-Low}(y_0)) = 0.06 \quad (21)$$

$$Rule_3 : m_3 = \min(\mu_{A-Small}(x_0), \mu_{B-Low}(y_0)) = 0.14 \quad (22)$$

$$Rule_4 : m_4 = \min(\mu_{A-Small}(x_0), \mu_{B-High}(y_0)) = 0.86 \quad (23)$$

Equation 24, 25, 26 and 27 are conclusion values of rules:

$$Conclusion_1 : c_1' = m_1 c_1 = 2.22 \quad (24)$$

$$Conclusion_2 : c_2' = m_2 c_2 = 1.66 \quad (25)$$

$$Conclusion_3 : c_3' = m_3 c_3 = 2.73 \quad (26)$$

$$Conclusion_4 : c_4' = m_4 c_4 = 13.81 \quad (27)$$

Final conclusion that indicates one dimension of the symbol in pixel unit is calculated as in Equation 28. The area that the symbol covered on the map is square of the conclusion value (Equations 29 and 30). The unit of the area is square pixels in Equation 29 and square millimetres in Equation 30:

$$c' = \frac{\sum_{i=1}^4 c_i'}{\sum_{i=1}^4 m_i} = 18.39 \text{ pixels} \quad (28)$$

$$(c')^2 = (18.39)^2 = 338.19 \text{ square pixels} \quad (29)$$

$$(c')^2 = (18.39 \times 0.28)^2 = 26.51 \text{ square millimetres} \quad (30)$$

Figures 4 and 5 show maps that have scaled polygonal representation and symbol-based representation. Figure 6 shows a map with a simplification technique to produce an adapted map. Adaptation is provided according to the display resolution capacity of the mobile device and the size of the spatial object. The map images in Figures 4,5 and 6 are 320X320 pixels.



Figure 4. Scaled polygonal representation

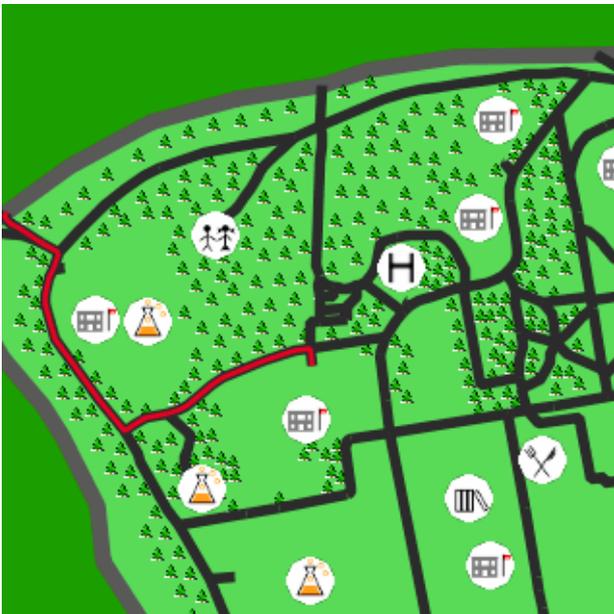


Figure 5. Symbol-based representation

In Figure 7, the comparison between polygonal representation and symbol-based representation can be seen graphically for 45 spatial objects. According to the graphic, x axis indicates real area values of the various spatial objects while y axis indicates scaled areas of the spatial objects. The real area value range ranges from 330 square metres to 12191 square metres. As shown in the graphic, the scaled polygonal area has a wider

range than the scaled symbol area. Consequently the symbol-based representation reduces big area differences among the spatial objects. The graphic has been drawn to 320X320 resolution.

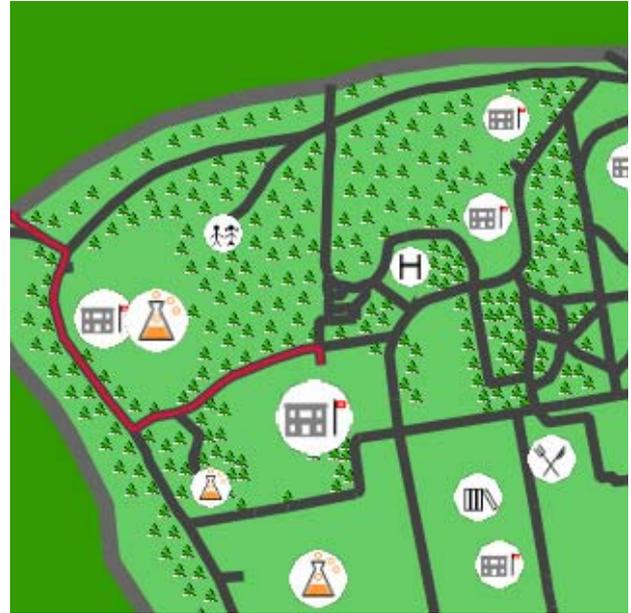


Figure 6. Symbol-based representation with simplification technique

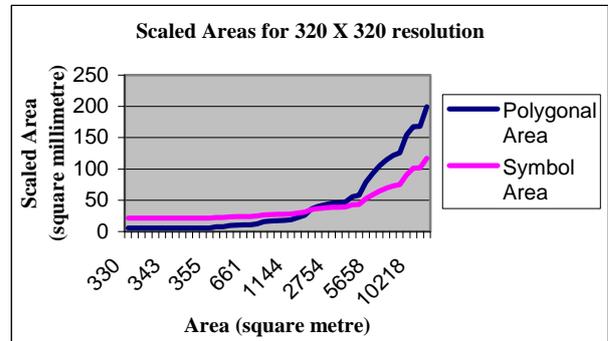


Figure 7. The comparison of symbol area with polygonal area

4. CONCLUSION

In the research, cartographic representation of the spatial data has been done more simply and more comprehensibly with the symbol-based simplification for mobile devices. To determine appropriate symbol size for the objects of the current visual level, a fuzzy logic solution has been proposed which depends on the original area of the object and the scale of the map. The solution has provided reasonable views for the mobile device.

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