Abstract
Geospatial information plays a vital role in today’s decision support system. Geospatial objects, the constituents of geospatial information, have both spatial representation and non-spatial/attribute values. These objects are represented as point, poly-line and polygon in maps. Though, the objects are crisply represented in geospatial maps, their region of influence depends on various factors and are often fuzzy. The buffer area of a geospatial object can be defined as the region up to which the object’s influence extends. The buffer area of an object depends on the parameter(s) related to its intrinsic qualities and also on other geospatial object. For example, the buffer area of a hospital depends on the type/quality of service available at the hospital and also on other objects, like nearness to transport network etc. This paper proposes a fuzzy based approach to estimate the region of influence (buffer area) of a geospatial object. To estimate the region of influence (RoI) of an object it is necessary to determine the parameters (both internal and external) defining its influence and the level/intensity of influence of the parameters. The buffer area of an object is determined by computing the object influence of the object at a certain geographical distance. The influence of object for that region is calculated by using fuzzy reasoning. The strength of the affecting factors (i.e., parameters) is determined using fuzzy if-then rules which reflect the marginal effect of each parameter on the buffer area. An case study has also been shown to demonstrate the efficacy of the proposed framework.

1. Introduction
In recent time, the geospatial information is becoming an inevitable component of decision making system, especially for socio-economic development. The geospatial information consist geospatial objects which have both spatial (point, poly-line, polygon) and non-spatial (attribute values) representation. These objects have varying regions of influence depending on their spatial and non-spatial information.

The region of influence (RoI) of a geospatial object is given by constructing appropriate buffer regions for the said object. The buffer area of an object gives the region where the object is active. For example, one wants to determine the suitable location for building a school in an area; for this purpose, it required to determine a location where the influence of other schools are very low. Further, one may try to build the school in such a location where it can serve a wide range area. This necessitates the need for determining the influence of the existing school(s) as well as the new school. By determining the buffer region and applying spatial topological relationship one can determine the total coverage area of a set of objects. The total coverage area for the set of objects can help in socio-economic development in several ways. The buffer zones are useful in various planning and management activities [5], the buffer zone of an object can be generated and can be stored as polygonal vector.

The interdependence among the spatial objects has been captured and modeled using a graph based model in [6]. In [8], the fuzzy reasoning has been used to find regions that are close to roads. For fire risk analysis [9], the ignition factors were identified and fuzzy logic and fuzzy inference are applied to these factors to analyze the risk factor. In the proposed approach, the buffer area of an object is defined using the concept of RMAC [1, 2] and fuzzy reasoning [7]. To determine the overall buffer area of an object a circular spatial region is considered taking the object as the center, and the object influence in each circular region is determined using fuzzy reasoning. The circular region with respect to an object is considered until the membership value of the exterior circular region falls below the threshold membership value. These entire circular region set can be called alpha level set of fuzzy regions. As we move far from the object, the radius of the circular region increases, and it may happen that one particular part may have positive influencing factor but other part may have a weak influence in the increment of the buffer zone. In this case the determined buffer zone can be less perfect. Therefore, to avoid such condition, as we move far from the object we divide each circular region into zones using spatial direction relations [3]. A spatial strategy is used in which the direction and distance relations are integrated to extract implicit spatial relations. Direction relations (e.g., north, northeast) constitute an important class of user queries in Spatial Databases and Geographic Information Systems. Alternative indexing method can be used for the retrieval of direction relation [4]. Spatial reasoning is a major part of comprehensive GIS. The buffer area of two objects may have some topological relationship (overlap, touch) between them. The spatial topological relationship between the fuzzy geographical can be defined using the spatial topological relationship between two crisp regions [1].
2. Region of Influence (RoI) of an object
The region of influence (RoI) of an object is given by the buffer area surrounding the object. Area of influence means the distance up to which the particular object can play its role. For example, the buffer area of a school can be given by the region within which the school can serve. The increment and decrement buffer area of an object is determined by various other spatial and non-spatial factors. For example, buffer area of a school is determined by (a) school location (b) transport condition of the locality (c) quality of teachers (d) performance of the school etc. The expansion or contraction of the buffer area will depend on the spatial and non-spatial factor. The membership function of each factor is determined first and then by applying fuzzy if-then rule, then approximate coverage (buffer area) of an object is determined.

2.2 Fuzzy membership functions for the influencing factors of the geospatial objects
The extend of influence of the various factors of a geospatial object is often fuzzy. Hence, it is necessary to define the fuzzy membership functions of the geospatial objects.

The concept can be explained with help of an example. Let us consider a health center object and the following influencing factors -

- Transport condition (number of nearby road segments)
- Facility in hospital (number of doctors, number of beds)

The membership function for each influencing factor is shown in figure 1.

![Membership functions](image)

Figure 1: Membership functions of the influencing factors

3. Estimating Region of Influence using Fuzzy Reasoning

3.1 Procedure for calculating buffer zone

**Input**: location of the Object (say O), for which the buffer area is to be calculated, influencing factors (say F), α = threshold membership value, distance from object = d, g = gap of distance between each iteration

**Output**: Buffer area of object.

// F is the collection of the influencing factors F
(factor 1, factor 2,..., factor 3) and F is a crisp set

**Step 1**: Membership functions of the influencing factors (linguistic variables) are described;

**Step 2**: Membership values of the factors obtained;

**Step 3**: Facts are determined;

**Step 4**: The rules are determined;

**Step 5**: 0th iteration is started a circle (Circle1) of radius g is considered taking object as the center.

// Object influence in this circular area has high object influence i.e. membership value 1.0.

**Step 6**: Divide the surrounding area of the object is into four zones;
Step 6: Circle 2 has been taken of radius 2g taking object as the center. 
// OI of this region has a membership value less than 1.

Step 8: Consequence is for each cone is obtained from 
Premise [fact] and Premise [rule]
Premise 1 [fact]: if factor 1 is high, factor 2 is low, ..., factor n is high
Premise 2 [rule]: if factor 1 is high and factor 2 is low ..., and factor n is high then
OI is high
Consequences (Conclusion) OI is high
// OI = Object influence

Step 9: OI of each cone is determined;
Step 10: Membership value for buffer area of each cone is determined;
Step 11: Consider the zone whose membership value is >= \( \alpha \)
Step 12: \( g = g + g \); 
Step 13: Determine \( d = g \); 
If \( d < \text{given} \ d \)
Step 14: Repeat step 7 to step 13 for the considered zone;
Step 15: Add the considered zone,
Step 16: Resultant buffer area for the object is returned;

In the example the above steps are followed to obtain the buffer area of a health center. For calculating the buffer area of the school the influencing factors are considered. The influencing factors (a) transport condition (b) facility in hospital. The factors are positive factors due to the following reasons -

- Increment of transport-condition = increment in object influence
- Increment of facility-in-hospital = increment in object influence

The way in which the buffer area of the health center will increase depends on the weight of the influencing factors. In the proposed framework the membership function for object influence (OI) is a sigmoid function and the universe of discourse is 0-10.

Figure 2: Represents the surrounding of the health center with multiple alpha cuts

The surrounding of the health center is divided into north (N) zone, south (zone), east (E) zone and west zone (W). The influence of the health center is calculated for each zone for each circular region. In figure 2 the circular regions are represented by A1, A2 .... An [1, 10]. The premises and the consequence for the influence of the health center follows.

Premise 1 (fact): If TC is good' and HF is good'
Premise 2 (rule): If TC is good and HF is good then OI is high
Consequence (Conclusion): OI is high'
TC = transport condition, HF = hospital facility, OI = Object influence (health center).

The fuzzy rule in premise 2 can written in simpler form (good \( \times \) good \( \rightarrow \) high). This fuzzy rule can be transformed into ternary fuzzy relation using Mamdani implication Rm [11].

Rm (good, good, high) = (good \( \times \) good \( \times \) high)
\( [TC \times HF \times OI \mu \text{good} (TC) \mu \text{good} (HF) \mu \text{high} (OI)] / (TC, HF, OI) \).

The resulting high can be expressed as:
\( \text{high}'=(\text{good}' \times \text{good}') \circ (\text{good} \times \text{good} \rightarrow \text{high}) \)

Therefore,
\( \mu \text{high}'(OI) = \mu \text{TC, HF} [\mu \text{good}' (TC) \Lambda \mu \text{good}' (HF)] \Lambda [\mu \text{good} (TC) \Lambda \mu \text{good} (HF) \Lambda \mu \text{high} (OI)] \)

\( = \mu \text{TC, HF} [\mu \text{good}' (TC) \Lambda \mu \text{good}' (HF)] \Lambda \mu \text{good} (TC) \Lambda \text{high} (OI) \)

\( = [\mu \text{TC} [\mu \text{good}' (TC) \Lambda \mu \text{good} (HC)] \Lambda \mu \text{HF} [\mu \text{good}' (HF) \Lambda \mu \text{good} (HC)]] \Lambda \mu \text{high} (OI) \)

\( = w1 \Lambda w2 \Lambda \mu \text{high} (OI) \)

\( w1 \Lambda w2 \) is the firing strength.

where, \( w1, w2 \) are the maxima of MF s of good \( \cap \) good', good \( \cap \) good' for TC, HF respectively. The pictorial representation of the algorithm is given in figure 3.
Determination of the buffer area in overlapping zone

If an area is covered by two or more similar objects, then that zone is allotted to the object with the highest Maximum Value (MV). Suppose a zone \(Z\) is overlapped by \(n\) objects then the zone \(Z\) becomes buffer area of the object with the highest Object Influence (OI). The buffer area in overlapping zone is determined by taking the union of OI value of each object.

\[
\mu_{OI1}(O1) \cup \mu_{OI2}(O2) \ldots \ldots \ldots \cup \mu_{OIn}(On) = \max(\mu_{OI1}(O1), \mu_{OI2}(O2), \ldots, \mu_{OIn}(On))
\]

The object with the maximum OI value is obtained and the overlapping zone allotted to that object.

Case Study

A case study has been shown for the proposed framework. A set of village health centers data has been considered and the buffer zone of each village health center has been determined from the above mentioned methodology. The effecting factors considered for the case study are, (a) transport condition (b) facility in health center; that is the number of beds and doctors in the health center. The functions of effective factors are defined. The function of each parameter is defined by user. The behavior of the buffer area function is analyzed by the user, here in the given case study the buffer area function varies linearly with the given parameters. Oracle spatial 10g is used to store the data. The value of each parameter is obtained from the database operations. The conclusion is drawn from predefined fuzzy if-then rules, and the buffer areas of the health centers are determined. The transport condition and village health centers, namely HC1 and HC2 in village 1 are represented in figure 4.

The membership functions for health center facility i.e. number of doctors and number of beds in health centers, transport condition and object influence are described in figure 1. The information about the health centers are stored in oracle 10 g database, the attribute information are retrieved from database. The number of beds in “HC 1” is between 15-20 and number of doctors is between 5-8. A circular area with respect to health center hospital of a radius 500 meters has been considered as the core area. The number of road segments passing or overlapping the core area is SEVEN; it is retrieved from database through spatial queries. The membership value in the core area is determined through Mamdani implication. The iteration stops if \(\alpha=0.35\) or the distance up to which buffer area is calculated is 200 meters. The distance interval is taken as fifty meter. Hence, maximum four iterations are required. The object influence in 0th iteration is calculated. The weight of each influencing factor is calculated for the core area (0th iteration). The weight for the facility in the health center is \(w_1=0.5\) and transport condition it is \(w_2=0.5\). The area for clipped object influence is clipped by \(w_1\Lambda_w_2\) the membership value for the clipped area is 0.5 (refer figure 5).
Therefore the membership value of $O_1=0.5\Lambda_1$, that is equal to 0.5. The membership value is greater than $\alpha$ ($\alpha=0.35$), therefore the area considered for 0th iteration is considered for next iteration. The membership value for each direction is calculated in for 1st iteration is calculated in similar manner. In 1st iteration, the hospital facility remains same, the number of road segments varies in each direction, the weight of hospital facility and transport condition is calculated. Transport condition in NE=1, Hospital facility is 0.5; the weights are calculated in similar way as in 0th iteration.

The membership value for the object influence in each direction can be given as -
NE= (0.01\Lambda_0.5)\Lambda_1.0=0.01; NW=(0.5\Lambda_0.5) \Lambda_1.0=0.5, SE= (0.5\Lambda_0.5) \Lambda_1.0=0.5, SW=(0.5\Lambda_0.5) \Lambda_1.0=0.5.

According to the proposed methodology (refer section 3.1) the zone with membership value greater than $\alpha$ will be considered. Therefore, buffer zone for next iteration is NW, SE, SW. The buffer zone for 2nd iteration will be NW, SE and SW.

The membership value for the object influence in each considered direction is
NW = (0.01\Lambda_0.5) \Lambda_1.0=0.01; SE = (0.5\Lambda_0.5) \Lambda_1.0=0.5; SW = (0.5\Lambda_0.5) \Lambda_1.0=0.5
The zone in SE and SW direction is considered for 3rd iteration.
SE = (0.5\Lambda_0.5) \Lambda_1.0=0.5; SW = (0.01\Lambda_0.5) \Lambda_1.0=0.01

After third iteration the resultant buffer area is determined given in figure 6.

For health center 2 (HC2) the number of beds greater than 5 and less than 10 and number of doctors are greater than 1 and less than 3. therefore the hospital facility (HF) for HC2 is low, hence membership value gone below $\alpha$ after 0th iteration. The resultant buffer area of HC1 and HC2 is given in figure 6.

![Diagram of Health Centers and Buffer Zones](image.png)

Figure 6: Representation of buffer area of health centers of a village

Hence, it can be observed (refer figure 6) the buffer zones (of HC1 and HC2) are influenced by the influencing factors. Thus the health centers have varying buffer regions.

**Conclusion**

The boundary of a polygon or location of a point or coordinates of the line can be defined by crisp values in a map. However, the influence of an object is not bound within the boundary defined in a map. In the given framework the area of influence of an object is determined using fuzzy reasoning. The buffer area of an object depends on its own quality and other spatial and non spatial parameter.

The buffer area of similar objects in same region may differ due to variation in their intrinsic qualities. Again, buffer area of similar object with same features may vary due to the variation in intensity of some other neighborhood geospatial features (that has an effect on increment and decrement of buffer area of an object).

In the given case study, the buffer area of two health centers in same region with similar kind of road network in its neighborhood is different because the medical facility of two hospitals are different.

**Reference**

[1] Ashley Morris and Frederick E. Petry. “UGML: an extension of GML to provide support for geographic objects with uncertain boundaries”. 7th International Symposium on Spatial Accuracy Assessment in Natural Resources and Environmental Sciences. 2006.


