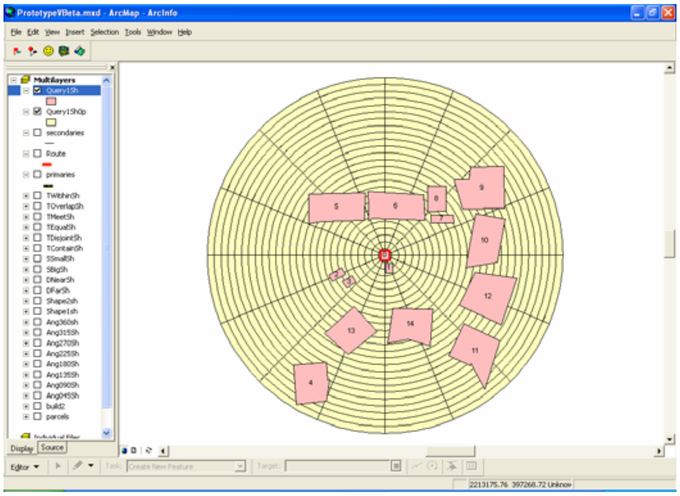


Figure 3 A Constructed Spiral Web

A spiral web is a spatial data structure that contains the data describing the sketch. The spiral web creation is determined by relative distance of reference object to the furthest object, diameter of the reference object and relative direction in a sketch's orientation. It uses rings and zones to represent a sketch. The object value (OV) of the sketch is determined by which ring and zone it falls on. The objects in the spiral web consist of {OID, OShape, OType, OV}. For spatial fields, OID is the numerical index of every object in the spiral web; OShape is the boundary of each object exists in the spiral web in string format, and OType is the geometry type of a spiral web object in generic format that is polygon, line or point. OV is the address on the spiral web. The spatial fields required are minimal and in generic format that most spatial data files like ESRI Shapefiles can provide. Figure 3 shows a spiral web created for the sketched query shown in Figure 2. It has a center object marked in red with another 29 objects, the spiral web is built with 50 rings and 16 zones based on the diameter of center object that is the reference object in the sketch and the distance from center to the furthest object.

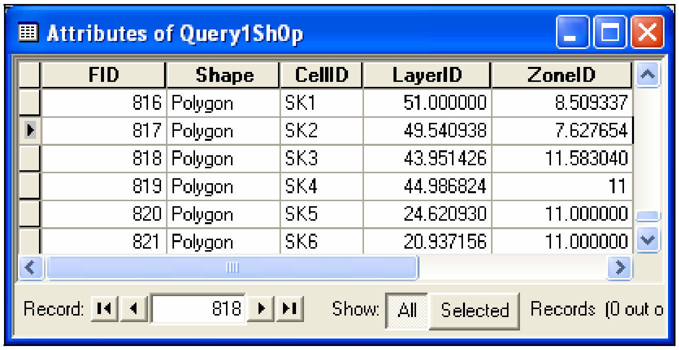
Once a spiral web representation is created, OV is computed for a sketch. There are 4 computation methods for OV namely multi zones single ring (MZSR), multi zones multi rings (MZMR), single zone multi rings (SZMR) and single zone single ring (SZSR). MZSR describes object that falls into more than one zone but only one ring, MZMR describes object that falls into more than one zone and one ring, SZSR describes object that falls single zone and single ring and SZMR describes object that falls in single zone and multi rings. OV computation for MZSR is modeled in Equation 1. As there are more than a zone involve, ∑(Zone) is computed by summing up all the zones being touched by the object. Since it involves single ring, ∑(Ring) is computed by the only ring being touched by the object. RN and ZN represent the ring number and zone number of Spiral Web. RV represents the ring value and ZV represents the zone value computed for a query object. OV for MZSR is modeled in Equation 2. For more than one zones involve, ∑(Zone) is the sum of all the zones being touched by the object. On the other hand, it also involves more than one ring, ∑(Ring) is computed by summing all the rings being touched by the object. Equation 3 shows OV computation for SZSR. Since there is one zone involve, therefore ∑(Zone) is modeled by the only one zone being touched by the object and ∑(Ring) is computed by the only ring being touched by the object. Equation 4 computes OV for an object that falls into multi zones single ring. Due to only one zone involve, therefore ∑(Zone) is computed by the only one zone being touched by the object. It involves more than one ring, so ∑(Ring) is computed by summing up all the rings being touched by the object. Figure 4 shows a portion of the computed object values for the query in Figure 3.

$$
\begin{aligned}
OV &= (ZV_n, RV_n) \\
ZV &= \sum_{n=1} [[ZN_1 + ZN_2 + \ldots + ZN_n]] \pm tol_z \\
RV &= \sum_{n=1} [[RN_1]] \pm tol_R
\end{aligned}
\qquad (1)
$$

$$
\begin{aligned}
OV &= (ZV_n, RV_n) \\
ZV &= \sum_{n=1} [[ZN_1 + ZN_2 + \ldots + ZN_n]] \pm tol_z \\
RV &= \sum_{n=1} [[RN_1 + RN_2 + \ldots + RN_n]] \pm tol_R
\end{aligned}
\qquad (2)
$$

$$
\begin{aligned}
OV &= (ZV_n, RV_n) \\
ZV &= \sum_{n=1} [ZN_1] \pm tol_z \\
RV &= \sum_{n=1} [RN_1] \pm tol_R
\end{aligned}
\qquad (3)
$$

$$
\begin{aligned}
OV &= (ZV_n, RV_n) \\
ZV &= \sum_{n=1} [ZN_1] \pm tol_z \\
RV &= \sum_{n=1} [[RN_1 + RN_2 + \ldots + RN_n]] \pm tol
\end{aligned}
\qquad (4)
$$



Attributes of Query1Sh0p

FID	Shape	CellID	LayerID	ZoneID
816	Polygon	SK1	51.000000	8.509337
817	Polygon	SK2	49.540938	7.627654
818	Polygon	SK3	43.951426	11.583040
819	Polygon	SK4	44.986824	11
820	Polygon	SK5	24.620930	11.000000
821	Polygon	SK6	20.937156	11.000000

Figure 4 Computed Object Values

IV. SKETCH SIMILARITY ASSESSMENT

For each sketch consists of a set of objects with OV, S = (S_1, S_2, …, S_n), there are zero to many sets of retrieved objects from the spatial databases, that is R={R_1, R_2, …, R_n}. For each retrieved configuration, R_n there is at least more than one retrieved object, R_n= {r_1, r_2, …, r_n}. The similarity of a retrieved configuration to a query, S_Q is made up of a list of assessed similarity for individual object pair, S_{OB} where S_n is the OV of the query object, R_n is the OV of the retrieved object, N is total number of associated object pairs, SX_n is the zone value for the query object, SY_n is the ring value for the query object, RX_n is the zone value for the retrieved object, RY_n is the ring value for the retrieved object, T_z is the total number of zone exists and T_r is the total number of ring exists in a Spiral Web. S_{OBJ} determines the similarity of each object in a query to a matched object from a database; hence the similarity of a query is determined by averaging the similarity values of the matched objects from database. It computes the differences with $(SX_i - RX_j)^2$ that is the difference of zone value and $(SY_i - RY_j)^2$ that is the difference of ring value. Equation 5 computes the structural similarity of an object in query to a retrieved object in a database. Equation 5 computes the structural similarity of an object in query to a retrieved object in a database. It computes the differences with $(SX_i - RX_j)^2$ that is the difference of zone value and $(SY_i - RY_j)^2$ that is the difference of ring value.

$$S_{OB}(S_i, R_j) = 1 - [\frac{(SX_i - RX_j)^2}{T_Z} + \frac{(SY_i - RY_j)^2}{T_r}] \quad (5)$$
$$where\ S_i \leftarrow OV_i, R_j \leftarrow OV_j$$

V. ROUTE FINDING IMPLEMENTATION

Once the retrieved destinations from spatial databases are ranked, the route processing continues. With the retrieved destination, the route from the user specified origin to to retrieved possible destinations are made utilizing Dijkstra Algorithm. In Zhan (1997), it is suggested that to obtain a one-to-one shortest path or one-to-some shortest paths, the Dijkstra algorithm offers some advantages because it can be terminated as soon as the shortest path distance to the destination node is obtained. Hence this research adopts Dijkstra Algorithm as shown in Figure 5.

```
begin
  queue_initialization(Q);
   for i=1 to n do
     d(i) = + infinite;
     d(s) = 0;
      while (Q != Null) do
         queue_removal(Q, i);
         for each successor node j of node i do
           if d(j) > d(i) + l(i, j) then
              begin
                 d(j) = d(i) + l(i, j)
                 queue_insertion(Q, j)
              end
 end
```

Figure 5 Shortest Path Algorithm

A prototype is implemented for this research using ArcGIS Desktop V8.1 and the maps from ESRI Sample Maps. The prototype allows a user to sketch out a route query. The user has to specify his origin on the system then sketch out a spatial configuration showing the destination and its neighborhoods. The sketch is preprocessed to eliminate overshoot, undershoot, redundancy and incompleteness as shown in Figure 1. The object marked with an 'X' is the specified building that is also the user's destination. Figure 2 shows the created spiral web for the query. Figure 4 shows the extracted details of the query. With the given origin and sketch consisting the destination surroundings, the prototype system retrieved the similar building configuration from the database that is shown in Figure 6. With the aids of the retrieved building configuration, the prototype then retrieved its parcel, primaries and secondary roads linking to the destination. Figure 7 shows the spatial database, a city map consists of roads, parcels and buildings that the query retrieves its results from. The best shortest route from origin to destination is plotted out in red bolded line.

Figure 6 Retrieved Buildings Based on the Sketch

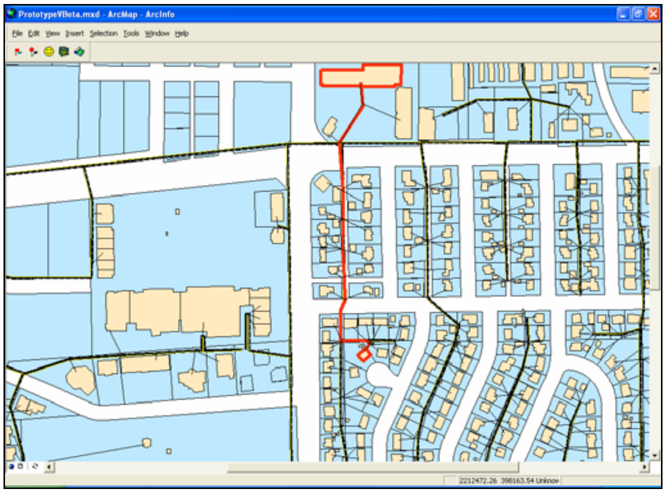


Figure 7 Retrieved Route and Destination

VI. RESULTS

This research has been implemented with a set of 120 route queries. The results are shown in Figure 8. The results are for queries consist of 1 to 20 objects. The Spearman and Wilcoxon correlation tests indicated the correlation of the retrieval with the databases. These results indicated that the retrieval by sketching a route finding query is feasible. The retrievals have medium to high correlation with the actual routes from the road map databases.

Query Set	**No. of Objects**	**Object Type**	**Spearman Test**	**Wilcoxon Test**
1	20	Polygon	0.90	0.08
2	20	Polygon	0.80	0.16
3	20	Line & Polygon	0.79	1.08
4	20	Line & Polygon	0.76	1.10
5	20	Line	0.80	0.20
6	20	Line	0.83	0.16

Figure 8 Query Sets and Results

VII. CONCLUSION

Sketching as a route query mode in in-vehicle navigation system may suffer from incomplete sketches. However the sketch processing model used takes into account the neighborhood relations and objects geometry to produce the best route match as a resolution to the incomplete sketching. Dealing with route query in navigation system, the safety issues which cause sketching not a preferable method during driving have to be taken into consideration. In future, the research will continue to improve the prototype to take into consideration the in-vehicle navigation and driver conditions. As to date, the elementary prototype has been implemented successfully to prove the applicability of sketching for route query.

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