Mobile Vector Map Generalization Methods for Location Information Search

Jin-Oh Choi, *Member, KIMICS*

Abstract—In the mobile environments for the vector map services, a map simplification work through the map generalization steps helps improve the readability of the map on a large scale. The generalization operations are various such as selection, aggregation, simplification, displacement, and so on, the formal operation algorithms have not been built yet. Because the algorithms require deep special knowledge and heuristic, which make it hard to automate the processes.

This thesis proposes some map generalization algorithms specialized in mobile vector map services, based on previous works. This thesis will show the detail to adapt the approaches on the mobile environment, to display complex spatial objects efficiently on the mobile devices which have restriction on the resources

Index Terms—mobile map, map generalization, vector map, location information search

I. INTRODUCTION

During the map production steps, the map generalization methods are important tools to improve the map readability. The methods are also used at various fields including the digital map service for many reasons. The map generalization techniques are usually developed for automatic map generation. The various generalization techniques have been researched up to recently but no formal rules have been developed[1]. Because the generalization algorithms need the highly specialized knowledge and the human decision, it is only possible to develop the field specific algorithm.

The map is considered as an integration of various information. It is the comprehensive integration of roads, buildings and other geographical features with non-geographical data such as climate and population data. The need for this kind of map services tends to place more importance and possibility on the mobile environment, with the rapid development of information and mobile equipment technologies [2]. For the mobile vector map services, map generalization techniques do very important role to reduce the size of transmission data by mobile network.

Figure 1 illustrates an example of the vector map services for mobile devices[3]. As shown at figure 1, over the wireless link, we face the challenge of the limit of data volume and client resources. Since spatial data volume tends to be large, it takes long time to transmit the spatial data and for a client to handle it. It result in a problem that mobile device must have a big memory capacity.

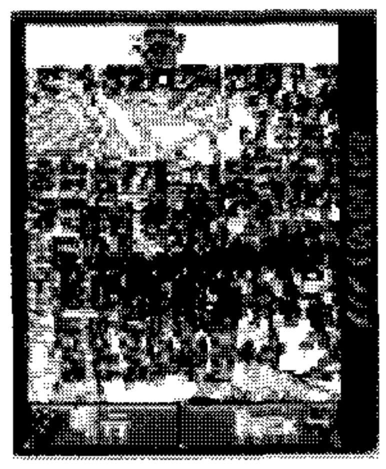

Fig. 1 Map Service at Mobile device

There are some requirements of map service for mobile devices. First, wireless mobile devices have limited resources. To display map in figure 1, we need much more hardware resources. Limited memory and capacity of display are major constraints on mobile clients. The constraint has caused problems of display failure in spite of successful transmission. Mobile map services via mobile phones thus will require the reduced map.

Furthermore, the bandwidth is limited in wireless communication. Because the spatial data have big data volume, the wide bandwidth will be required for data transmission. The mobile environment has far less bandwidth availability than a wired environment. This makes it difficult to guarantee a quality map and a reasonable response time. The response time delay involves in narrow wireless bandwidth and unstable network condition. Figure 2 show the increment of client response delay according to the increment of data volume[3]. To solve this problem, we need to reduce map data volume to transmit. For this purpose, the map generalization methods for mobile map services need to be developed.

This thesis sets the focus at how to reduce transmitting information, how to separate deleting data without omitting the significant information and how to display mobile map efficiently. The main idea is to develop generalization algorithms for mobile vector map services. These methods make it possible to generate a simplified map for mobile service.

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Jin-Oh Choi is with the Department of Computer Engineering, Pusan University of Foreign Studies, Pusan, 608-738, Korea (Tel: +82-51-640-3539, Fax: +82-51-640-3038, Email: jochoi@pufs.ac.kr)

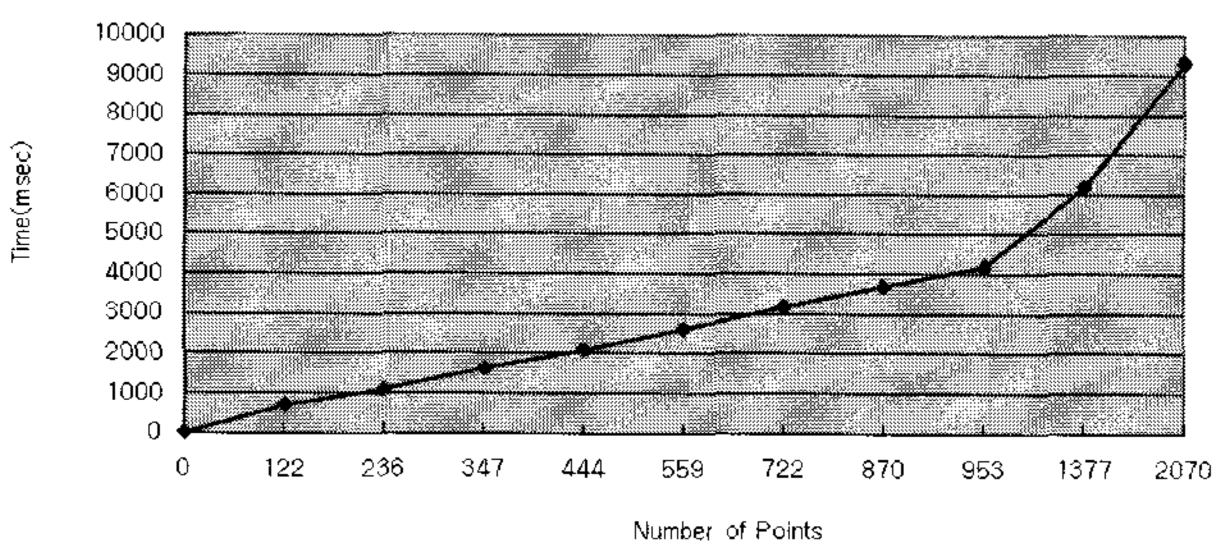


Fig. 2 Client Delay Time

We can develop a new special map database for mobile services by modifying the existing map database. But it is not acceptable for these reasons. First, it takes redundant cost. Second, it can omit some significant information. We need to generate dynamically reduced map with important information from the existing map database.

The organization of the remaining parts of the paper is follows. Section 2 reviews the related works on the topic and Section 3 introduces proposing map generalization methods and some examples of the algorithm implementations. Finally, the conclusions of this paper are in Section 4.

II. Related Work

Generally the researches on the map generalization have focused on the efficient ways to get desired output at reduced scales. Others has adopted the generalization to computer assisted map-making automation and map generation for presenting statistic information.

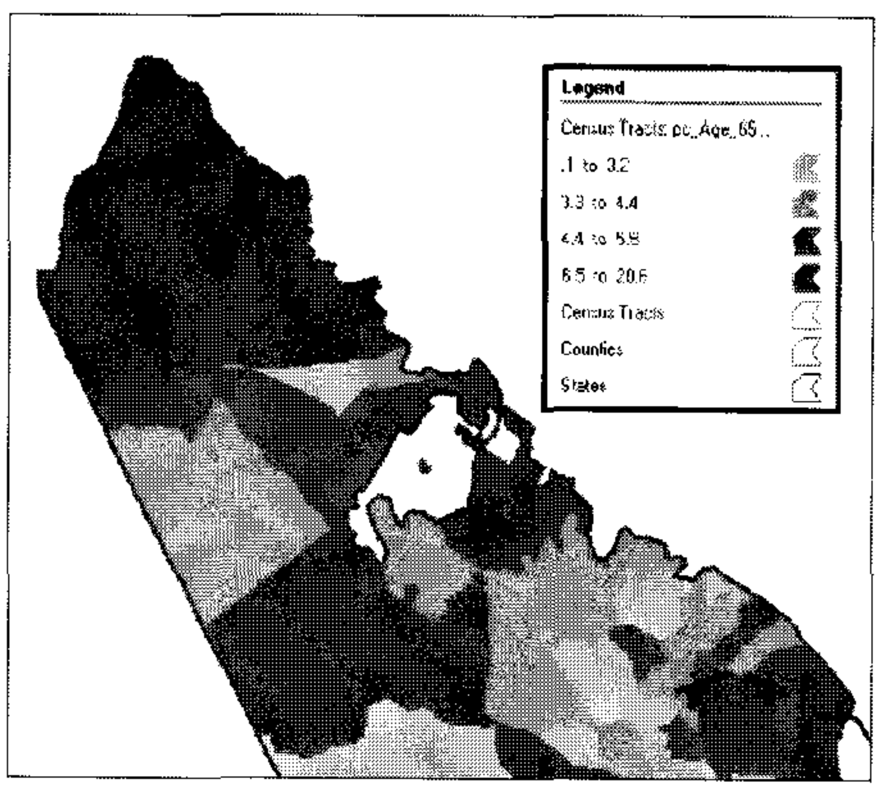


Fig 3. Example of Map Generalization : Population Density Display

Figure 3 shows an example of typical map generalization results. Generalization technique with strategies and operating algorithms has been proposed in 1970. The efforts to standardize the generalization algorithms started from 1991 in ICA(International Cartographic Association). They made working group for formalization of generalization and report some research results[4][5]. ESF(European Science Foundation) also made research about the status of digital map generalization through the GISDATA program. NCGIA (National Center for Geographic Information and Analysis) made specialist committee(initiative 8 : Formalizing Cartographic knowledge) for map generalization and announced the research reports[6].

Up to these days, there have been many studies about map generalization[7][8], however, the basic problems of generalization is left without unique solution yet. Only the classification and definition of generalization operation was defined at a conceptual level, as the results of past efforts. Because the detail algorithm requires too much efforts and professional decision, most related researches remain in an early stage. But, many research is attempting to develop detail algorithm or rule-base operation.

This paper proposes some generalization algorithms that are specialized on mobile vector map services. The aim of this paper is not to make a complete map at a certain scale by reducing object to the given scale, but to generate a map dynamically for mobile service with many constraints.

III. Generalization Algorithms

This paper proposes 4 generalization operators. They are Selection, Simplification, Filtering, and Displacement. This paper assume that there are 3 display scales(small(1:25000), medium(1:15,000) and large scale(1:5000)) and there are 3 kind of virtual map layers(basic, milestone and Interesting layer)[3].

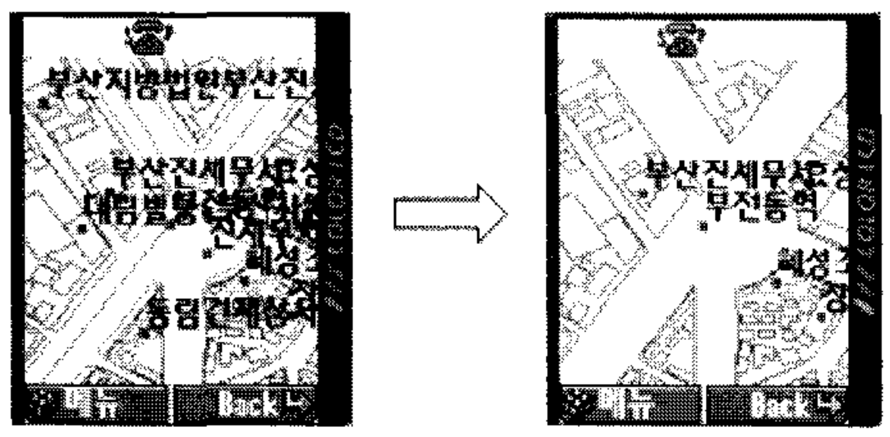
```
selection(map, scale, newMap) {
 for i<map.numOfLayers {
  if map.layer[i] is in BasicLayers[]
   if map.layer[i] is in preSet[sacle][B]
    addLayer(newMap, map.layer[i])
  else if map.layer[i] is SearchLayers[] {
   for j<map.layer[i].numOfObjects
    if map.layer[i].object[j] <> searchObject
     delObject(map.layer[i],j)
   addLayer(newMap, map.layer[i])
  }
  else if map.layer[i] is in MilestoneLayers[]
   if map.layer[i] is in preSet[scale][M] {
    leaveSomeObjects(map.layer[i], numOfMSPerLayer[scale])
    addLayer(tempMap, map.layer[i])
   }
 }
 for k, total<numOfMSObjects[scale] {
  x=getPriority(tempMap, k)
  addLayer(newMap, tempMap.Layer[x])
  total=total+tempMap.Layer[x].numOfObjects
 }
}
```

Fig 4. Algorithm of Selection Operator

For Selection operator, this thesis adopts the priority based approach. Following the display level and virtual map layer, the physical layers get their each priority. For example, at medium scale, for basic layer, only the 2 or more lane road layer and building layer get the highest priority. The other physical layers can be selected only if there are remaining space at full map, and if their priority is the highest among the remaining layers. For milestone layer, the priority is given the following sequence:

government building, bank, hospital, and so on. The number of selected features are pre-defined as 'munOfMSObjects[medium scale]'. Figure 4 shows the algorithm of Selection operator.

The implementation results are shown at figure 5. Before applying Selection operator, the map size was 1208 points. The size is reduced to 1009 points after the operation.



1208 points 1009 points

Fig 5. Implementation of Selection Operator

For Simplification operator, there are 3 sub-operators to perform the simplification: degree check, clipping, and symbolization. Figure 6 shows the algorithm of Simplification operator.

```
simplification(map, scale) {
 for i<map.numOfLayers //degree check
  if map.layer[i].type=(LINE | POLYGON)
   for j<map.layer[i].numOfObjects
    for k<map.layer[i].object[j].numOfPoints
     if checkDegree(p[k],p[k+1],p[k+2],deg[scale])=DELETE
       delPoint(map.layer[i].object[j],k+1)
 for i<map.numOfLayers //clipping
  if map.layer[i].type=(LINE | POLYGON)
   for j<map.layer[i].numOfObjects
    for k<map.layer[i].object[j].numOfPoints
     if checkVisiable(p[k])=FALSE
      delPoint(map.layer[i].object[j],k)
 for i<map.numOfLayers //symbolization
  if map.layer[i] is in symTarget[]
   if map.layer[i].type=POLYGON
    for j<map.layer[i].numOfObjects {
     p=getCenterPoint(map.layer[i].object[j])
     delObject(map.layer[i],j)
     addPolyObject(map.layer[i],p.x,p.y)
    }
}
```

Fig 6. Algorithm of Simplification Operator

Degree check sub-operator reduces middle point among 3 points if their degree is in the pre-defined range, 'minDeg[scale]' and 'maxDeg[scale]'. The range is larger at small sacle. Figure 7 shows the idea of degree check operation.

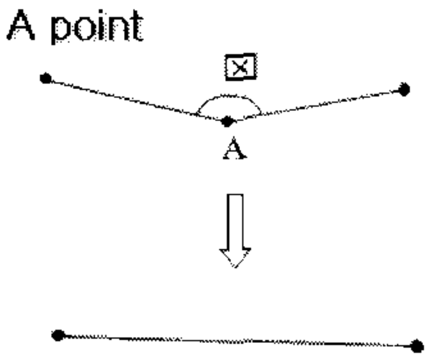
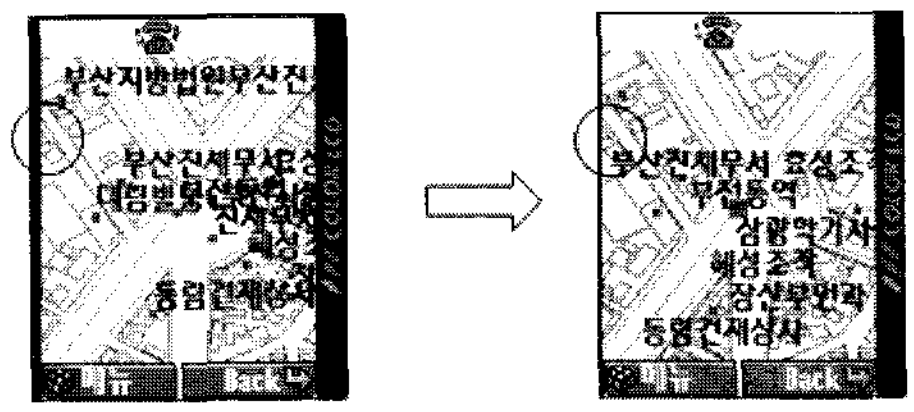


Fig 7. Degree Check Sub-operator

The implementation results of degree check sub-operator are shown at figure 8. Before applying degree check sub-operator, the map size was 1208 points. The size is reduced to 938 points after the operation.



1208 points 938 points

Fig 8. Implementation of Degree Check Sub-operator

Clipping sub-operator removes non-shown points of partly-shown objects. If map server sends only showing part of partly-shown objects the data size of transmitted data can be dramatically reduced. Figure 9 shows the idea of clipping operation.

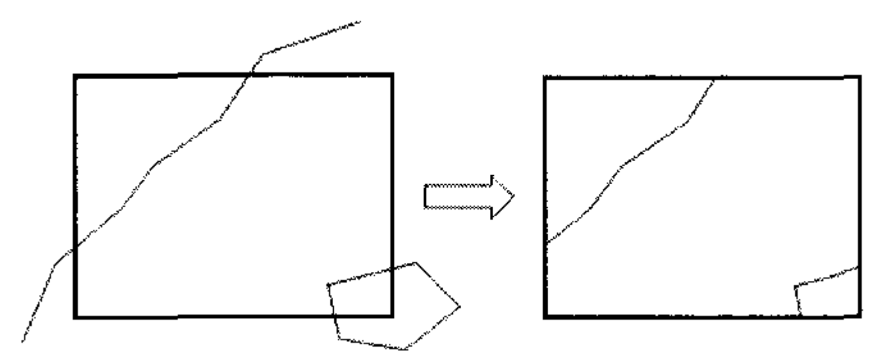
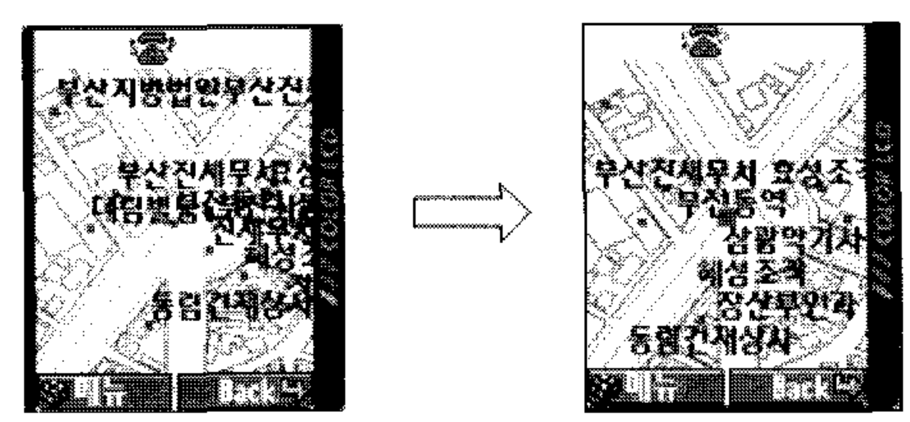


Fig 9. Clipping Sub-operator

The implementation results of clipping sub-operator are shown at figure 10. Before applying clipping sub-operator, the map size was 1208 points. The size is reduced to 670 points after the operation.



1208 points 670 points

Fig 10. Implementation of Clipping Sub-operator

Symbolization sub-operator transforms complex object to simple symbol. The data size can be reduced to the size of the symbol. Figure 11 shows the example of symbolization operation. At figure 11, 12 points object are simplified to 4 points object. This operator may be applied at some layers in which the exact shapes are not important.

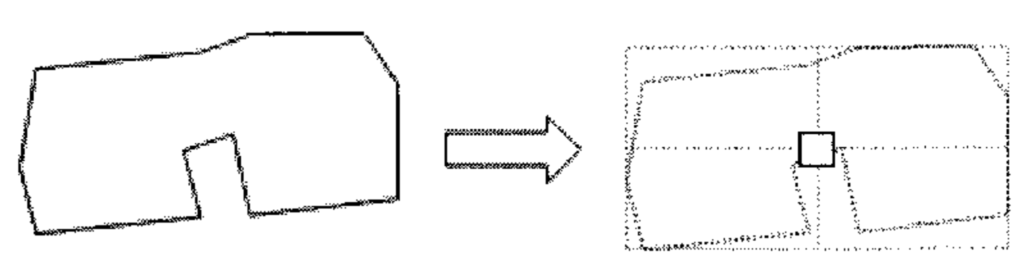
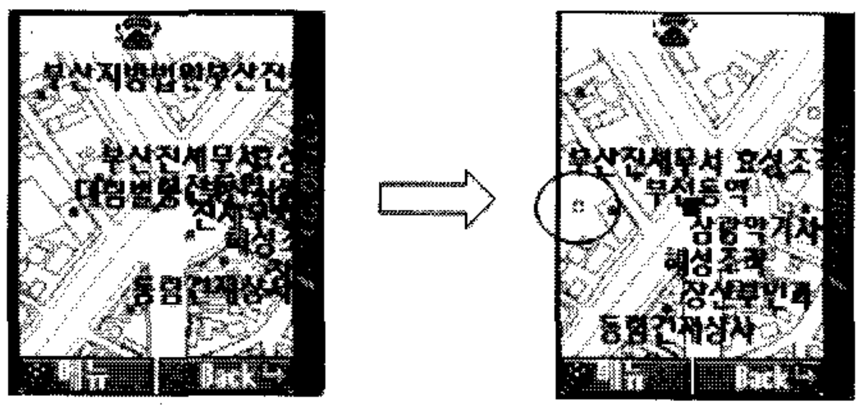


Fig 11. Symbolization Sub-operator

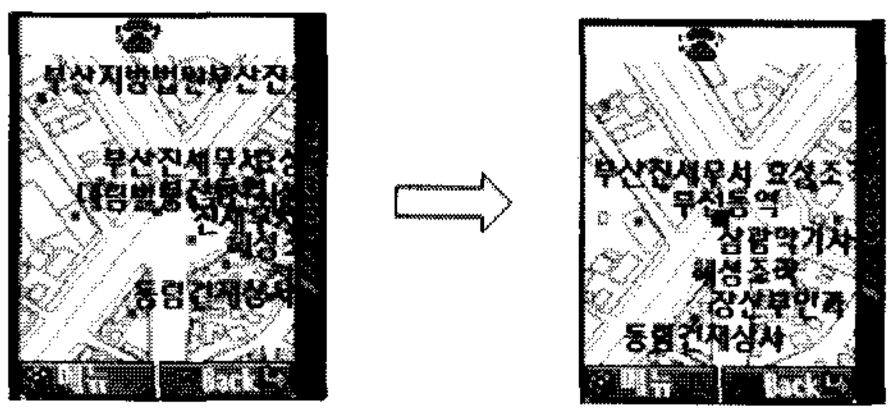
The implementation results of symbolization sub-operator are shown at figure 12. Before applying symbolization sub-operator, the map size was 1208 points. The size is reduced to 1156 points after the operation.



1208 points 1156 points

Fig 12. Implementation of Symbolization Sub-operator

The implementation results of all 3 sub-operators are shown at figure 13. Before applying simplification operator, the map size was 1208 points. The size is reduced to 566 points after the operation.



1208 points 566 points

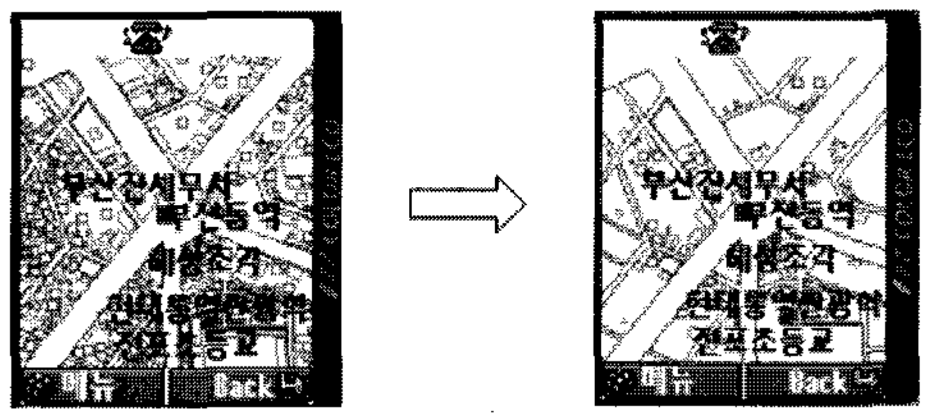
Fig 13. Implementation of Simplification Operator

For Filtering operator, this thesis adopts the probability based approach. To reduce map size up to pre-defined 'filterThreshold', the objects are removed at some probability that is decided by the distance to the center point of the map. The near objects have a small value. The center part objects, that is, have high probability to survive. Figure 14 shows the algorithm of Filtering operator.

```
filtering(map) {
 for countPoints(map) > filterThreshold
  for i<map.numOfLayers
   if map.layer[i] is in filterTarget[]
    if map.layer[i].type=POLYGON
     for j<map.layer[i].numOfObjects {
      dist=getDistance(map.layer[i].object[j])
      if getDelProb(dist)=TRUE
       delObject(map.layer[i],j)
     }
}
```

Fig 14. Algorithm of Filtering Operator

The implementation results of Filtering operator are shown at figure 15. Before applying the operator, the map size was 2416 points. The size is reduced to 919 points after the operation. At this experiment, the 'filterThreshold' value was 1000.



2416 points 919 points

Fig 15. Implementation of Filtering Operator

For Displacement operator, this thesis searches the best place to display a label. Without this operation, the labels are overlapped and cut off. For the upper half area, this algorithm decides the best place from up to down direction. For the lower half area, this algorithm searches the best place from down to up direction. These approaches improve the chance of finding more good results. Figure 16 shows the algorithm of Displacement operator.

```
displacement(map) {
 for i<map.numOfLayers
  if map.layer[i] is MilestoneLayers[]
   for j<map.layer[i].numOfObjects
    addObject(msLayer, map.layer[i].object[j])
 sortByYCord(msLayer)
 for 0<=i<msLayer.numOfObjects/2
  p=findUpBestPoint(i,msLayer)
 for msLayer.numOfObjects>i>=msLayer.numOfObjects/2
  p=findDownBestPoint(i,msLayer)
}
```

Fig 16. Algorithm of Displacement Operator

The implementation results of Displacement operator are shown at figure 17. Before applying Displacement operator, the labels are not shown entirely. After the operation, more good results are produced.

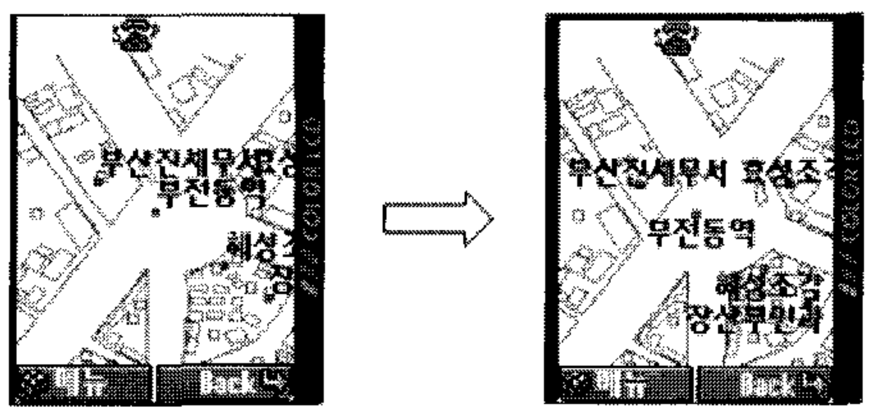
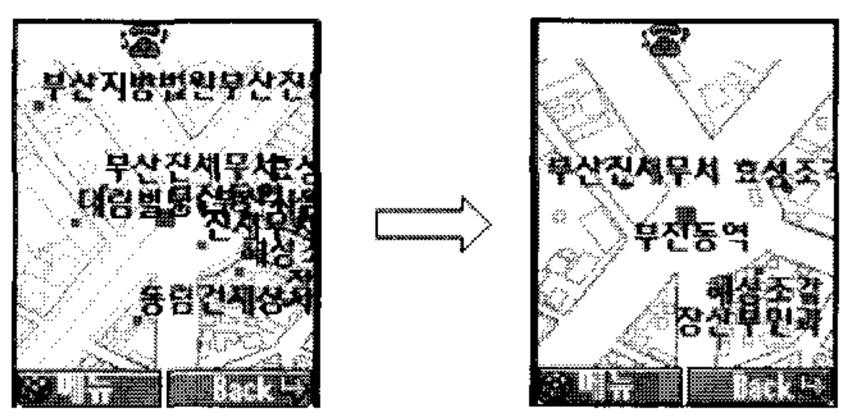


Fig 17. Implementation of Displacement Operator

The implementation results of applying all operators are shown at figure 18 and figure 19. Before applying generalization operators, the map size was 1208/3476 points. The size is reduced to 483/919 points after the operations at each scale.



1208 points 483 points

Fig 18. Results of Applying All Operators : Large Scale

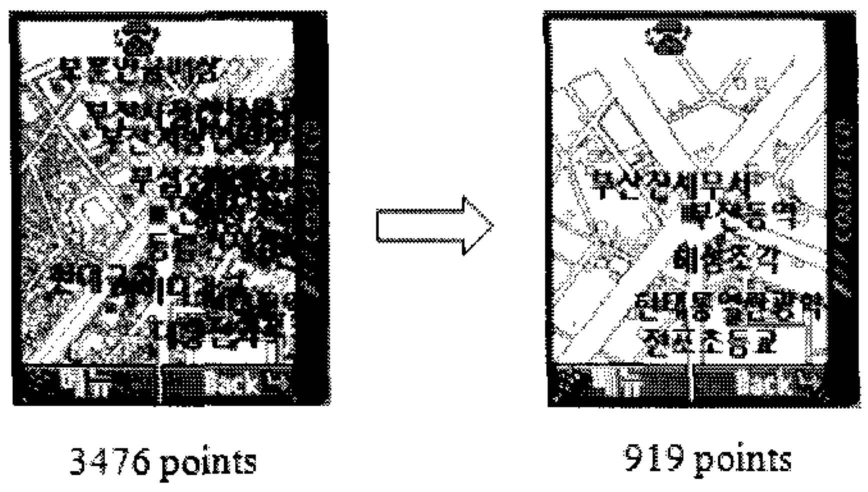


Fig 19. Results of Applying All Operators : Medium Scale

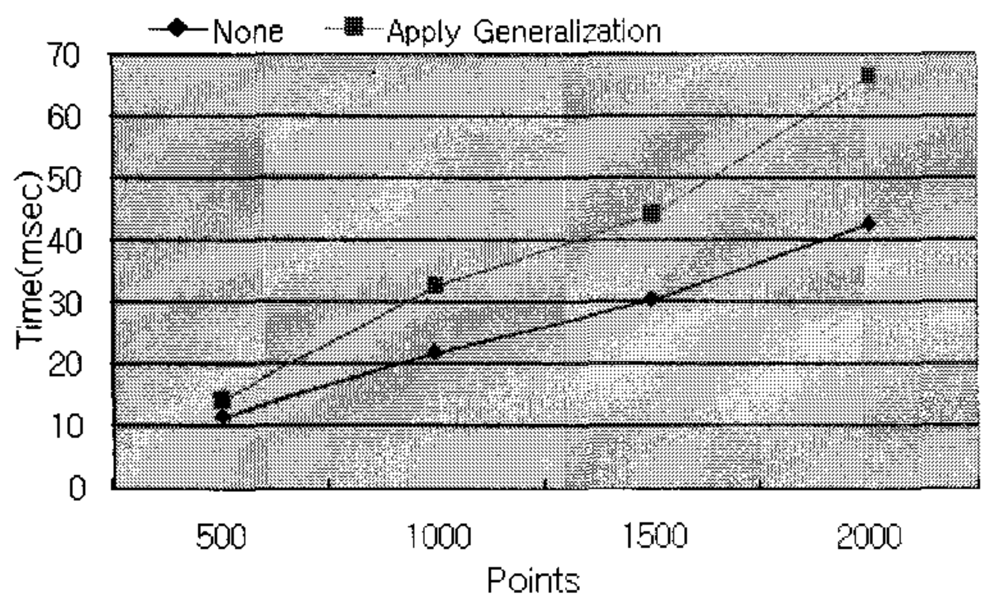


Fig 20. Overhead of Generalization Operators

Figure 20 shows the processing overhead of generalization operators. For processing 2000 points map, the overhead times are less than 30 msec. This overhead can be ignored if we consider the benefits. We can reduce the mobile bandwidth and generate displayable map at mobile devices.

IV. CONCLUSIONS

This thesis proposes generalization algorithms for the environment of mobile vector map services. The environment requires reducing the transmitting data size from server to clients. The environment also requires generating displayable map at the mobile client devices. To satisfy these requirements, specific algorithms are developed. They are Selection, Simplification, Filtering, and Displacement operators.

As a implementation and experiment results, the effects and benefits are confirmed. By the developed generalization algorithms, data size reduced to about 30% of original size. This makes it possible that the mobile device can receive vector map by wireless and display at the small size display area. The experiments also find that the overhead of the generalization operators are not so considerable.

Further researches are needed to refine the current algorithms. The more efficient and precise methods could be developed by further experiments. The much more reduced data size and less operating time are the targets of the refinement. The new generalization operator also can be developed. The formal generalization operators include Elimination, Aggregation, Symbolization, Exaggeration, etc[10]. These further researches should consider the correctness criteria. At least, the transformed or simplified spatial objects obey the topological correctness.

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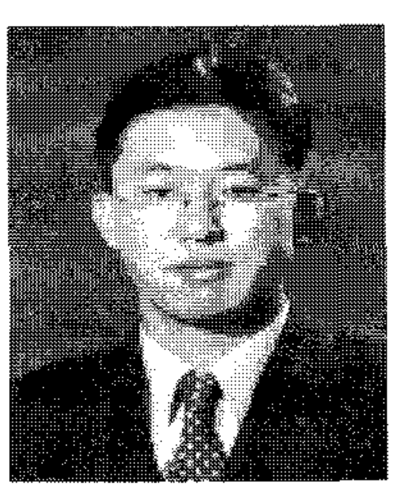

Jin-Oh Choi

Received his B.S., M.S., and Ph.D. degree in Department of Computer Engineering from Pusan National University in 1991, 1995, and 2000 respectively. From 1991 to 1992, he worked at the Hyundai Electronics as a computer system develop staff. From 1998 to 2000, he worked as a professor of Kyungdong University. In 2000, he joined the Department of Computer Engineering of Pusan University of Foreign Studies, where he is presently an associate professor. His research interest is in the area of mobile GIS, vector map display, and LBS.