MORPHING TECHNIQUES: TOWARDS NEW METHODS FOR RASTER BASED CARTOGRAPHIC GENERALIZATION

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Abstract

This article focuses on the results achieved so far from the investigation of the possibility of applying morphing techniques in cartographic generalization procedure. The fundamental questions of our research are: a) is it possible to use morphing techniques for cartographic generalization in order to produce or to contribute to the production of generalized maps? If yes, how and to what extend the morphing techniques can be useful in the multi-scale spatial databases creation? b) If no, is it possible the morphing techniques to indirectly help in other ways to the creation of multi-scale spatial database and in the generalization process? This article follows up the efforts of a preliminary research (Pantazis et al., 2009), regarding the possible implications of morphing techniques in multi-scale spatial databases design and generalization techniques and new procedures for multi-scale spatial databases creation (Pantazis et al., 2004; 2005; 2008). Nowadays, it is difficult to produce generalized raster maps using solely morphing software. Nevertheless, the morphing techniques may help in the generalization process. The accuracy of generalized cartographic features could significantly be improved using morphing techniques in the raster generalization process. In addition animated maps could easily be produced using morphing software, thus indicating the relation and the change between cartographic features of different scales.

1 INTRODUCTION - THE CONTEXT OF THE RESEARCH

This article follows up the efforts of a preliminary investigation (Pantazis et al., 2009), completed by the Research Group SOCRATES of the TEI of Athens, Greece, regarding the possible implications of morphing techniques in multi-scale spatial databases design and generalization techniques and new procedures for multi-scale spatial databases creation (Pantazis et al., 2004; 2005; 2008). The contribution of the morphing techniques focuses mainly on the manipulation of 1:25.000-1:500.00 scales and in the possible creation of intermediate scales. More specifically it concerns the results of applying morphing techniques to generalized raster maps development and/or their production. The research is supported and partially funded by the TEI of Athens, Greece.

2 OBJECTIVES AND STRUCTURE OF THE ARTICLE

The objective of our research concerns the application of morphing techniques in order to create middle scale generalized maps. We have use a set of 25k, 50k and 100k scale maps (fig. 1). The first part of our research (Pantazis et al., 2009) involves the following questions:

a) Is it possible to use the morphing techniques for cartographic generalization (raster based generalization) in order to produce or to contribute to the production of such maps? In case of a positive answer, how and to what extend the morphing techniques can be useful in the multi-scale spatial databases creation?
b) In case of a negative answer, is it possible the morphing techniques to help in other ways in the creation of multi-scale spatial database and in generalization process?

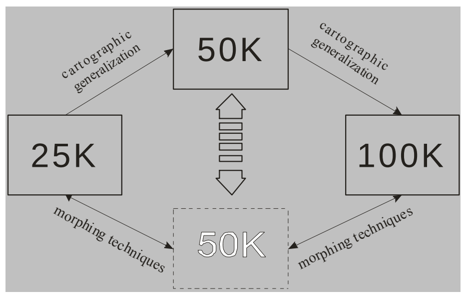


Figure 1. Schematic chart of morphing techniques application in topographic maps

At this phase we have investigated:
- The reliability of the morphing results
- The use of animation software to create morphs, warps and other effect with one or more maps, trying to align, resize, and crop the pictures (raster maps) to achieve the best morphing results. We have examined if the resulting animation can be computed and displayed real-time creating dynamic/animated maps.
- The identification of the "key objects" and the "skeleton" of the multi-scale database that could be useful if they play the role of control points and lines in the application of morphing techniques.
- The use of thematic layers in the application of morphing techniques.
- The use of different filters on the images and frames in order to improve the final result.
- The application of morphing techniques with one image only.

This article includes six sections and it is organised as follows: Firstly, (section 1,2) presents the follow up of the preliminary work in the field of applying morphing techniques in the cartographic generalization (Pantazis et al., 2009). Section 3 summarizes the relation between the concepts of generalization, multi-scale spatial databases and morphing including first phase's research results. Section 4 briefly presents the research questions of the second phase and indicates relevant work. In section 5 and subsections (5.1, 5.2, 5.3, 5.4) we try to answer the questions of the second phase of this research. Finally, section 6 discusses the conclusions and further perspectives of this research.

3 CARTOGRAPHIC GENERALIZATION, MULTISCALE DATABASES, MORPHING AND FIRST PHASE RESEARCH RESULTS

The creation of maps at a smaller scale (e.g. 1: 50.000) from those at a larger (e.g. 1: 25.000), is a process that is called “cartographic generalization”. In the classic account of McMaster and Shea (1992, at p. 3) in the cartographic generalization process, the digital generalization is defined as “*the process of deriving, from data source, a symbolically or digitally-encoded cartographic data set through the application of spatial and attribute transformations*” (see figure 2 example of cartographic generalization). We mention that our study deals with “raster – based” generalization, a term that dates back from the ‘90s (e.g. McMaster & Shea 1992; Mc Master & Monmonier, 1989).

A multi-resolution, multi-scale, multi-representation spatial/cartographic database of 2D and/or 3D can be defined as a database with raster and/or vector entities and / or other data set of multiple scales; of which their entities are inter-connected between them (with gen-spec, composed by and other relations); and of which their entities are georeferenced at the same geodetic system (coordinates, projection, datum). Also, as a database that can be used to store the same geographic reality, (e.g. real-world-representations, phenomena, events etc.), at different levels of precision, accuracy, scale and resolution with multiple representations of the same entity in different scale if necessary, and with all the necessary integrity controls allowing or not the simultaneous appearance of entities and /or data sets (including toponyms) in different scales (Pantazis et al., 2008).

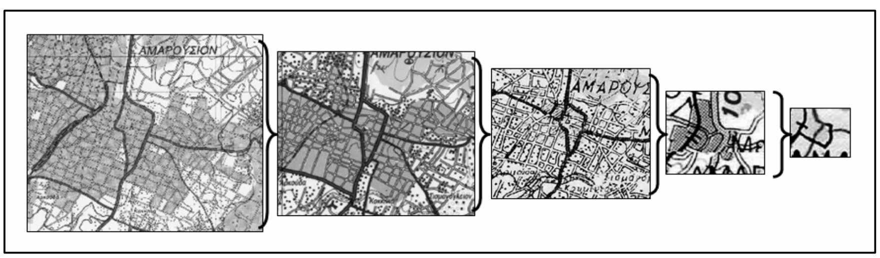
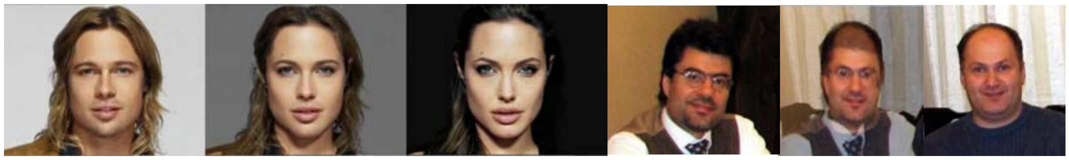


Figure 2. Examples of generalization techniques in polygons cartographic objects (Greek topographic maps from 1:25.000, 1: 50.000, 1:100.000, 1:250.000 1:500.000, Pantazis et al., 2008)

Morphing techniques (figure 3) could be summarized as the integration of concepts of fade in –fade out and at the same time applying resampling techniques. The early morphing techniques started to be applied in the films using a cross-fading from the motion picture of one actor or object to another. Later more sophisticated cross-fading techniques were employed that vignette different parts of one image to the other gradually instead of transitioning the entire image at once.



(a) (b)

Figure 3. Morphing examples.

Map morphing – by "map" we mean raster maps, scanned paper maps or satellite images- involves graphic transition procedures between raster images between two topographic maps under the scope of continuous generalization. Accepting that morphing is the change (or morph) of one image into another through a seamless transition and remembering that cartographic generalization is the transformation of a map of scale a to another of scale b, where $b<a$, we identify easily a first similarity between the procedures, thus answering the first question of our research (Pantazis et al., 2009). The neccesary indentification of corresponding points between the two images in morphing techniques and also in the cartographic generalization procedure is a second answer, that is; a generalized map has always common parts with the maps that derive from (Pantazis & al., 2009). Thus, we can define map morphing as the procedure of stretching/distorting of any scale topographic map aiming at a raster-based cartographic generalization.

There are fundamental differences between vector (point, lines, and area/features) and raster-mode generalization. Such differences are the different operators that must be used, the separation of geographic and attribute information in vector mode, the fact that the attribute information is always included in raster –mode generalization, etc. (Pantazis et al., 2009). One of the first conceptual frameworks for raster –mode generalization, proposed by McMaster & Shea (1992), includes four fundamental categories of generalization operators: (1) structural (2) numerical (3) numerical categorization (4) categorical generalization. The morphing techniques we have investigated in the first phase of our research could eventually give some elements to fill successfully the gap between two different maps of scales a and b, helping in the creation of a map of scale c where $a<c<b$. Some useful conclusions are drawn from the study of the first phase (Pantazis et al., 2009):

1. The change in the order of the raster maps does not influence the intermediate result (intermediate frames).
2. The use (and choice) of characteristic corresponding points in the morphing could be particularly useful in our case.
3. The number of the characteristic corresponding points affect the appearance (visualization) of the seamless "distortion" of the morphing steps (intermediate frames).
4. Different morphing algorithms can deal better with specific generalization operators.

5. Application of morphing techniques in specific areas of the maps could also be useful in order to produce parts of an intermediate scale generalized map instead of using the entire image (map) at once.
6. Most of the morphing techniques are based on the interpolation techniques (between the left image (first map) and the right image (second map)). The process is called cross-dissolve. In this case if the two images have identical size and shape the result is better than having images of different size and shape.
7. The morphing techniques of wrapping (= to make the two images of equal size and identical shape by co-registration, using some corresponding points and vectors on the first (or "before") and second (or "after" image)) is particularly interesting to our objective.
8. There is a similarity between the morphing techniques and geo-referencing and rectification techniques.

4 RESEARCH QUESTIONS AND PERTINENT STUDIES

Although there are a few pertinent articles, there is a lack in literature or studies to treat the exact hypothesis of our research using a holistic approach in the application of morphing techniques in generalization process. Moreover, only a few articles deal with raster data generalization. For example, Li (1994) examined the raster data generalization in relation with the mathematical morphology. Yet, there is a dearth of literature regarding the combination of morphing techniques raster data and generalization. Pantazis et al. (2009) briefly review the most important relevant literature. Nollenburg et al. (2008) present some solutions in the "continuous generalization" problem. They also state that this kind of interpolation process in computer graphics and computational geometry is known as *morphing.* Related issues are also discussed by Bespamyatnikh (2002); Cecconi, & Galanda (2002); Cohen et al. (1997); Jones & Ware (2005); Lecordix, et al. (2005); Li (2007); Sezgin (2001). Cecconi et al. (2002) also describe new methods of on-demand mapping in the scope of scale changing and automated map generalization. Reilly & Inkpen (2004) define map morphing as an interactive visualization technique that provides animated translation from one map to another. Finally, closer to our idea is the study of Li & Wong (2008) that describe an animation for multi-scale representation of spatial data. The authors attempt to use morphing technique to animate 40 generalization operations differentiated by Li that makes them more intuitive (Li, 2007).
Also, morphing techniques have been used in remote sensing, for improving the interpretation of different kinds of satellite images. Although this topic is beyond the cartographic generalization issue, some useful conclusions are drawn for morphing cartographic features. For example, Wimmers & Velden (2004) demonstrate morphing techniques to enhance satellite meteorological images. Ohira & Wada (n.d.) use images from SPOT vegetation instrument data to morph them in order to understand the dynamics of changes in forest.
The above literature review allow us to conclude that the morphing techniques have been applied and used by the scientific community recently and limited to some aspects

of the generalization problem. Probably this is because morphing techniques have been developed at the last years through user friendly software.

5 SECOND RESEARCH PHASE RESULTS

The results of the second phase of our research show and confirm that morphing techniques could be useful in generalization process in raster maps (see fig. 4). The results of this phase are shown in detail in the following paragraphs.

Image 1 Image 2 Image 3 Image 4 Image5

Figure 4. Maps from the Swiss Federal Office of Topography representing scales 1:25.000 (image 1) and 200.000 (image 2). Image 3 is resulting after morphing application techniques (resulting frame raster map similar to 1:50.000 and/or 1:100.000 scale map of the same area). Images 4, 5 maps at scales 1:50.000 and 1:100.000 (Parts of maps – images 1, 2, 3, 4 (Cecconi, 2003)).

5.1 COMPARING MORPHING RESULTS WITH INTERMEDIATE SCALE GOOGLE-MAP IMAGES

In order to test the reliability of results produced using morphing process in topographic maps is to compare them with known maps like Google-maps. A good matching between these different maps means that morphing results can be reliable and be used in cartographic generalization process applied in raster data (fig. 5).

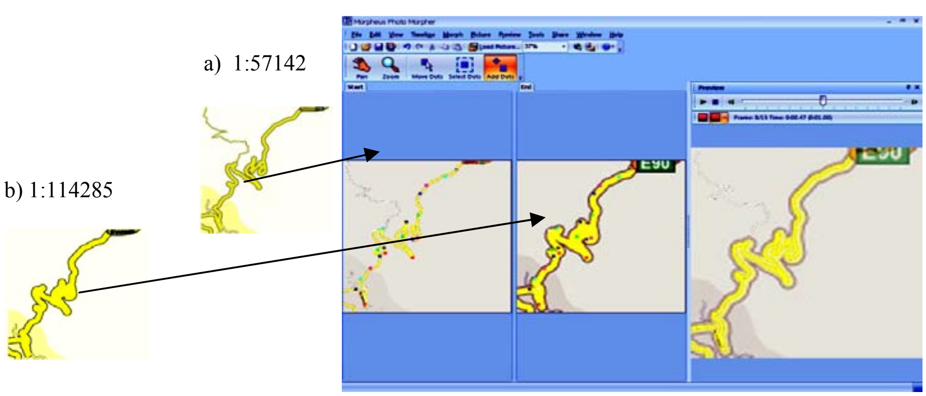


Figure 5. Comparison of the intermediate morphing results with Google-maps snapshots

We have taken maps from Google with different scales of a specific area. From this set we have selected the largest and the smallest scales as inputs (a and b in fig. 5) in the morphing software. The next step was to compare the intermediate morphing frames with the Google-map samples. This comparison helps us to find out the quality of the morphing results.

5.2 "KEY OBJECTS", MORPHING TECHNIQUES AND CARTOGRAPHIC GENERALIZATION

Common points in "key objects" between topographic maps in which morphing techniques may be applied could improve the final result. The "key objects" are objects which appear in more than one map of different scale. The most common "key objects" that appear in topographic maps are roads- crossroads, limits of cities, hydrographical network, etc. The "key objects" are chosen according to their importance, which is calculated from their appearance in the different scale maps. The most important 'key object' is the one that appears in all scales. To create the best morph (in our case the intermediate scale generalized map), we try to place dots on and around all key features of the first raster map (Fig. 6). For example, in our case key features could be the crossroads, trigonometric points, or points in the hydrographical network. The more dots we place, the smoother our end result is. For every dot we place on the raster map of the bigger scale, a corresponding dot, or "partner" dot, appears on the raster map of the smaller scale. Generally the morphing software gives the possibility to adjust the placement of each partner dot so that the key features morph just the direction/way we like them to.

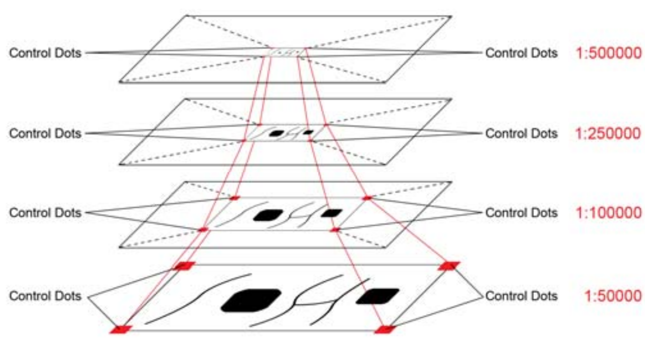


Figure 6. Dot placement in "key cartographic objects" during the application of morphing process.

5.3 MORPHING TECHNIQUES, CARTOGRAPHIC GENERALIZATION AND FILTERS USE

The use of different filters could have significant impact in the morphing results. Morphing techniques have been applied to 25k as an input image and 100k as an output image. We attempt to observe if any intermediate morphing phase shows similarity with a 50k map. The idea of borrowing morphological tools (operators) from digital image processing for generalization purposes dates back to '90s (e.g. Li, 1994). In the frame of the application of image processing to raster images of topo-maps, we can focus to the special features of the image (map), like roads, lines, etc. and to make therefore the morphing procedure less time and cost consuming. Image processing analysis, like edge detection/enhancement techniques (e.g laplacian edge detector, sobel filtering, etc.) is used to optimize the visibility of the images before morphing steps in the manner of edges (or lines) enhancement. One way to perform edge detection is with the use of Sobel non-directional edge detection filter. This type of gradient filter can enhance the vertical and horizontal edges of the image, it is less sensitive to noise and due to the nature of the maps that they have many linear features we can assume that this filter is suitable to enhance raster images of topographic maps before the morphing techniques. The implementation of Sobel filter to 25k image with the procedure gives better results when morphing the enhanced image with the 100k, in order to create an inter-step similar to 50k map. The image created under this procedure was more closed to the original 50K topographic map. We may argue that images produced after selectable enhancement of their fine characteristics, refine the inter-steps of the morphing procedures and are suitable for map morphing creation of middle scale topographic maps.

5.4 MORPHING ORDER PROCESS

The change in the order of the raster maps has not any significant change in the intermediate frames of the morphing application steps. Several tests show that the order of the raster maps does not change anything in the inter-steps (intermediate frames) of the morphing procedure. This is clearly obvious in adjacent scales where morphing from 1:25K to 1:100K and vice-versa give almost identical products (fig.7).

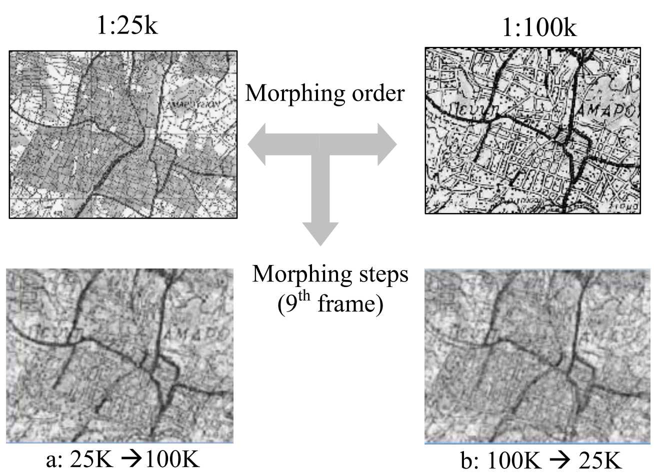


Figure 7: Order change of the raster maps has not any significant effect in the intermediate steps: (a) and (b) are almost identical.

5.5 MORPHING OF SIMULATION'S RESULT

The main idea is that we use only one image at the morphing procedure. In this case, the second image will be the result of a simulation process of the initial image (e.g. urban growth simulation process or a generalized topographic maps, see fig. 8). To achieve that, we need a simulation process software which will design a model of the second image used in the morphing process.

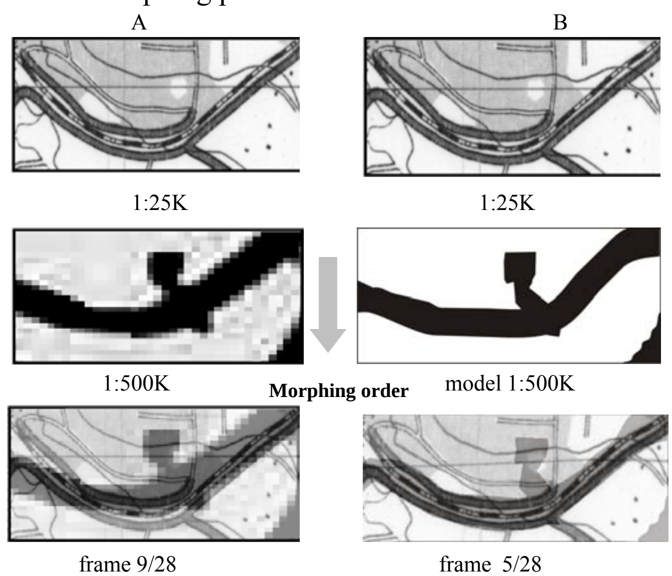


Figure 8. Example of application of predicted morphing from 1:25K and 1:500K map. (A): morphing with original maps, (B): morphing with model map

6 CONCLUDING REMARKS

This article discusses partly the results of the final phase of a research showing the potential applications of morphing techniques in generalization of raster data (raster topographic maps). This research is based on the creation of a multi-scale cartographic/spatial database that was developed in the framework of a bilateral research project between China and Greece (2000-2008).

Nowadays, more and more sophisticated morphing software appear, that makes us to believe, that our efforts can lead to the creation of an automated morphing process for developing intermediate scales generalized maps. In addition, the application of morphing techniques constitutes a simple way to create animated. Those animated maps may show a) the gradual change between two topographic maps of adjacent scales of the same area or b) the gradual change between different kinds of cartographic objects that appear in different chronological times in the same area (e.g. urban areas).

Morphing techniques could be applied in separate thematic layers e.g. roads layers, forest layers etc. The difficulty occurs when we need to integrate all layers of the entire generalized map. Our suggestion after several efforts is that the morphing is more useful and easily performed in the generalization process when applied in raster maps with important information and not only in thematic layers. The main of this article is whether we can use techniques of morphing in cartographic generalization rather than going further to examine technical details including objects removal, toponyms morphing problems and morphing algorithm structures. The later relates to our further perspective research aims.

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