Using Morphing For Information Visualization

Wolfgang Müller and Marc Alexa

Darmstadt University of Technology

Abstract

Information visualization deals with the graphical display of data. For quantitative data, data values have to be mapped onto an appropriate visual scale. Several visual scales are well known, i.e. position, size, form, color, texture of graphical objects.

We propose to use morphing or warping techniques to generate visual scales. Morphing between two graphical objects results in an interval of in-between objects, which represent a smooth blend between the base objects. By morphing between an object of this interval and a third base object, we construct a two-dimensional space of visual representations. Repeating this process, a space of any given dimension can be constructed. These spaces of visual representations are ideally suited for the visualization of multivariate/ multidimensional data.

CR Categories and Subject Descriptors: I.3.3 [Computer Graphics]: Picture/Image Generation; I.3.6 [Computer Graphics]: Methodology and Techniques.

Additional Keywords: information visualization, morphing, visual scales

1 INTRODUCTION

The visualization of data involves a mapping of data values to visual attributes or graphical representations. For quantitative data, data values have to be mapped onto an appropriate scale defined by the variation of such an attribute or object.

The principles of mapping of scalar data to scales of visual attributes are well-known for a number of basic scales. In color mapping, data values are mapped to appropriate hue of lightness values. Scatter plots are based on the principle of mapping data values to positions, or more exactly, to distances from an axes. Other variables often applied for such purposes are scale, form, and texture. Bertin [9] describes a general methodology of how to select an appropriate mapping to these visual variables and how to combine them. Cleveland gives a ranking of their effectiveness [16].

While the mapping of data to these variables can be quite effective, some problems stay. First, a mapping of application data to these fundamental variables involves an abstraction. If the user is familiar with the idea of this mapping, he may understand the generated visualization pretty good. However, often the application context is lost and the visualization which was applied to simplify the analysis of the data involves an analysis step or experience by its own. Second, it is not easy to visualize a number of parameters using these fundamental mappings only. Usually, the visualization of multiparameter data involves the generation of application specific models and solutions. General solutions and general scales do not exist for this purpose.

Figure 1: Scale produced by morphing between mona lisa faces

A general methodology for generating application specific graphical scales for the visualization of quantitative data would be helpful. In this paper we propose such a general methodology based on the idea of morphing. A more detailed and formal description of this technique is described in [1].

If we want to assign visual attributes to a parameter scale an intuitive approach is to find visual attributes that represent the bounding values. Data values in between these bounds have to be generated by blending between these visual attributes of the bounds. However, we can also think of applying this approach using more complex graphical objects.

For many types of graphical objects such blending is possible by means of metamorphosis techniques, commonly referred to as morphing. Figures 1 and 2 show simple scales produced using morphing between images of mona lisa faces. Morphing is usually applied to generate animations and, as such, exploited only for blending between two objects. But we can also morph among multiple objects by performing several morphing operations between two objects subsequently. This way a multidimensional space of objects is defined, and each of the morphing operations adds another dimension to the space.

The strength of using morphing techniques to generate visual representations of data becomes evident when applied to multivariate data. As mentioned before, it has been proven difficult to find intuitive visual representations for multivariate data and multidimensional objects. By morphing among multiple objects one could visualize multivariate data as elements of a space of graphical objects. Actually, we view morphing as a superset of traditional ways

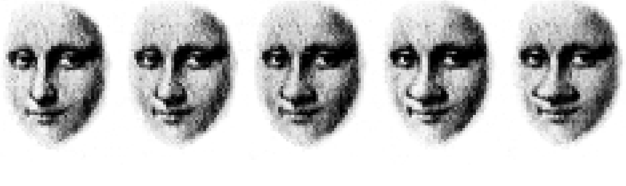

Figure 2: Another scale produced by morphing between mona lisa faces

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The authors are with the Interactive Graphics Systems Group (GRIS), Department of Computer Science, Darmstadt University of Technology, Rundeturmstr. 6, 64283 Darmstadt, Germany
{alexa,mueller}@gris.informatik.tu-darmstadt.de

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NPIV 98 Bethesda MD USA

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to produce glyphs, since most techniques could be described in terms of metamorphosis.

Before we explain in more detail how to map data to graphical base objects and then construct a specific object from a given value, we give a short overview over morphing-techniques and their applications.

1.1 Morphing

Feature-based image morphing was first introduced in the areas of film by Smythe [33] for the feature films *Willow, Indiana Jones and the last crusade* and *The Abyss.* These and other traditional applications are discussed in detail in Wolberg's monograph on image warping [34]. In order to make the feature specification easier Beier and Neely [4] presented a technique using line transformations, which was used in the production of Michael Jackson's *Black or White* video clip. Recent image morphing algorithms use scattered data interpolation methods [4],[29] or specifically suited deformation techniques [22],[23],[27].

Techniques for morphing between volume models make use of representations in the frequency domain [20], the wavelet domain [19] or the spatial domain. The latter can be seen as extensions of image morphing. The extension of Beier and Neely's technique to three dimensions is discussed in detail in [25].

Morphing between polygons consists of two parts: Finding the correspondences between the two shapes and an interpolation process. Sederberg et al. give a deterministic solution (based on energy minimization) to the first problem in [31] and a solution to the second problem in [30]. Shapira and Rappoport use the star-skeleton representation of polygons to solve both problems [32].

An almost generally applicable technique for morphing between polyhedral objects was introduced by Kent et al. in [21]. The idea is to find a polyhedron that contains the topological structure of both source shapes. Carmel and Cohen'Or demonstrate new techniques for the merging step in [12].

Coher'Or et al. use distance fields to find suitable morphs between three-dimensional shapes [17]. Edelsbrunner has developed a representation of shapes that allows deformation and linear interpolation [18].

Morphing among more then two images has been proposed currently by Lee, Wolberg and Shin [24]. Cheng et al. use the deformable surfaces of Edelsbrunner to construct shape spaces [13]. Alexa and Müller axiomize morphing and derive spaces from any morphing technique [2][3].

2 FROM DATA TO VISUAL REPRESENTATIONS

In our understanding morphing among multiple objects (the *bases*) results in multidimensional spaces. For our purposes it is sufficient to think of the morphing operation between two objects as a three-valued function. This function takes a source and target object along with a real-valued transition parameter to produce an *in-between* object. By definition, the transition parameters 0 and 1 reproduce the source and the target object, respectively. For most morphing techniques the transition parameter is limited to the unit interval, i.e. morphing can only interpolate between the objects.

Obviously a space of objects constructed from two base objects is one-dimensional. Adding another object adds a degree of freedom as long as the objects are affinely independent. Inductively, a space comprised of n base objects is of dimension n - 1. The composite objects in this space are 'mixtures' of the base objects. Hence, barycentric coordinates can be used as a intuitive representation of the space's elements.

Figure 3: Mona Lisa-faces scales as visual representations of city ratings in the U.S.

If we want to use a space of graphical objects derived from morphing for the visualization of data, we are faced with two problems:

1. Given a data set, what are appropriate base objects and how do we map data to the barycentric coordinates?
2. Given a barycentric coordinate and a morphing technique that operates on two objects only, how do we generate the corresponding element of the space?

We will address these problems in the following subsections.

2.1 Mapping Data to Coordinates

Our visualization technique is based on the selection of a number of visual object attributes and the specification of visual prototypes representing a high data value against the global neutral object state. The visual prototypes are the base objects of the representation space. The correspondence between visual prototypes and data values induces a mapping from the data to barycentric coordinates, which again are used to construct the actual visual representations (the latter map is explained in the next section).

We demonstrate the above procedure at two application examples. In both examples we visualize data about U.S. cities from [10]. Note that the examples are meant merely to demonstrate the techniques employed, and not to show the most effective way of communicating information.

In the first example we use distorted images of Mona Lisa's face as base objects and visual prototypes (see figure 1). The idea of using faces as visual representations dates back to Chernoff [14] and is advantageous due to human's native ability to recognize facial expressions. Note how morphing techniques add realism and additional degrees of freedom to this concept: An undistorted image is used as a representation of a neutral value. This image is distorted to represent good economical situations (Mona blinks), many recreational facilities (Mona smiles), high crime rates (Mona's nose gets wider) and bad health care situations (Mona's cheeks tighten). Thus, the neutral face represents cities with bad economy, few recreational facilities, low crime rate, and good health care. In order to find data values that correspond to the intended meaning of the representations we simply scan the values for minima and maxima. The neutral face represents the smallest value in economics rating, recreation rating, and crime rating, but a high health care score. The other faces are based on the neutral face and add their specific char-

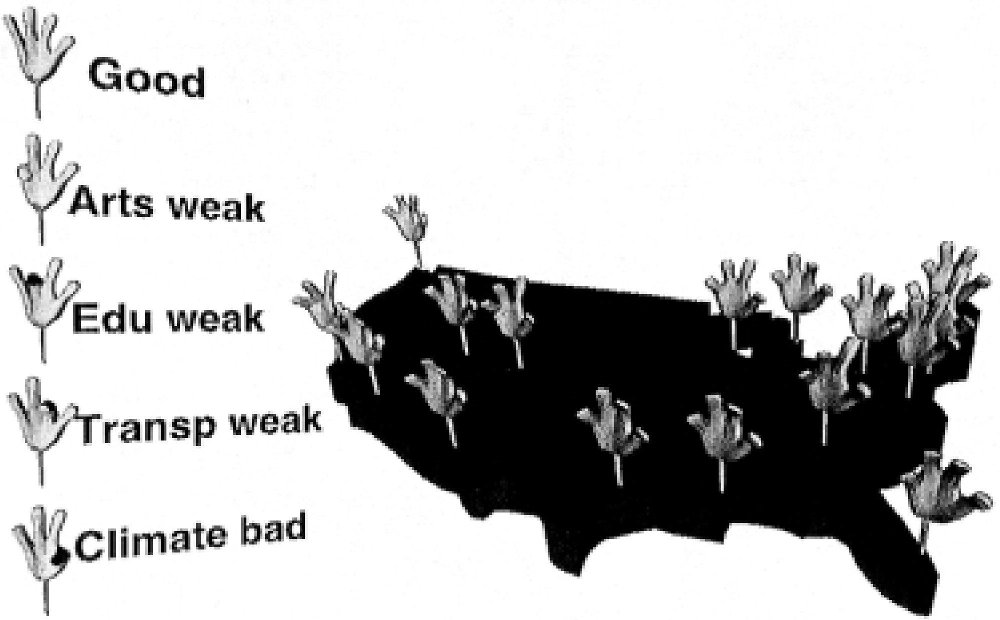

Figure 4: 3D hand glyphs generated by metamorphosis for the visualization of city ratings.

acteristics (e.g.smile).

The mapping from data values to barycentric coordinates could be derived as follows: Each base image represents a vector of data values. Then the barycentric coordinate of each of the bases is derived from the relative position of the data vector on the scale given by the neutral element and this base. In general one can use any linear or non-linear mapping to generate barycnetric coordinates form the data vectors using their relative position inside the vectors represented by the base objects.

In the second example we use the 3D-model of a comic figure's hand (see figure 2). Note that navigating in the 3d-scene (http://www.igd.fhg.de/~mueller/npic.wrl) yields better access to the information than a single projection on 2D. The idea of using hands as glyphs is that, similar to faces, gestures are recognized intuitively by a human observer. However, we do not claim that this visualization is appropriate and effective for the given data. In this simple visualization example the neutral position is an open hand and each variate is represented by the flexion of one finger. A more sophisticated model could use hand gestures similar to those from sign languages. The process of connecting data values with objects is exactly the same as in the example above, as is the data set, now using the categories climate, economics, transportation and the arts. This time, of course, the construction of the in-between objects works differently. The construction process, in general, is explained in the next section.

The general idea of assigning graphical objects to boundary values of the data opens up a new research direction for glyph generation. The main point to elaborate on would be the effectiveness of know morphing techniques to generate the scales of visual representations. From the point of information visualization it is imperative that the base objects are as different - in terms of perception - as possible. The main question regarding the search for appropriate base objects are:

- What is difference of graphical objects and how could it be measured?
- What is orthogonality of base objects? Obviously we need a definition of distance, but that alone is not sufficient.
- How does deformation relate to other visual attributes in terms of perception?

These are open questions.

2.2 Construction of Objects

We give an algorithm that computes objects from given barycentric coordinates and given base objects. The algorithm is independent of the object type. In case of feature based morphing techniques an object consists of the graphical model and the features (or more generally: all necessary input for the morphing technique). In our first example, the base objects are images including several feature points. The feature points are necessary to align the undistorted and distorted versions of the faces. For the geometric deformation step ("warping") we use radial basis functions as described in [4]. In the second example the models are morphed by linear interpolation between the vertices of the 3D models. Since linear interpolation would result in unnatural flexion of the fingers an additional in-between object was supplied for each finger. Note that we use these additional models only for the purpose of a more natural impression of the hand movement and not to increase the degrees of freedom.

Assume we want to synthesize an object A with a given barycentric representation the algorithm could be described by a recursive definition. We give an informal description here and point the reader to [2] for a derivation of the algorithm based on algebra and a discussion about mathematical issues, e.g. associativity. In the first step we morph between to of the base objects according to their relative weights. The resulting object is morphed with another base object. The parameter is derived from the sum of the weight of the first two base objects and the third one. This step is repeated until the last base object is added. The morphing parameter is always calculated from the sum of weights of the already incorporated objects relative to the weight of the object to add.

Note that this algorithm is optimal: We have to combine n objects, each object pair with a given operation. Obviously we have to apply this operation at least n-1 times.

3 REMARKS

Most techniques to produce glyphs could be described in terms of morphing. For that reason, producing glyphs by metamorphosis is a superset of glyph visualization in general. But in order to take advantage of the gained flexibility different visual prototypes and morphing techniques have to be evaluated.

In our examples, we intentionally resigned from employing traditional ways of iconic visualization to focus on the extra characteristics of visualization by metamorphosis. One can easily add attributes like color, scale of the icons, or textures (see [26]) to visualize additional parameters or for redundant mapping. For instance, one could scale the hands in figure 2 according to the population of the cities.

A nice by-product of this concept is the possibility to smoothly interpolate between two visual representations. Thus, the approach is ideally suited for displaying time series or grand tour visualization ([5],[11]). Also, averaging between several objects is an intrinsic operation in this visualization technique. Consequently it could be combined with multiresolution techniques for interactively exploring the data on various levels of abstraction ([35]).

The strength of visualization by metamorphosis lies in its flexibility to deal with different visual prototypes of any object class. Thus, the visualization can be tailored to the data in a general and easy way.

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