Morphable guidelines for the human head

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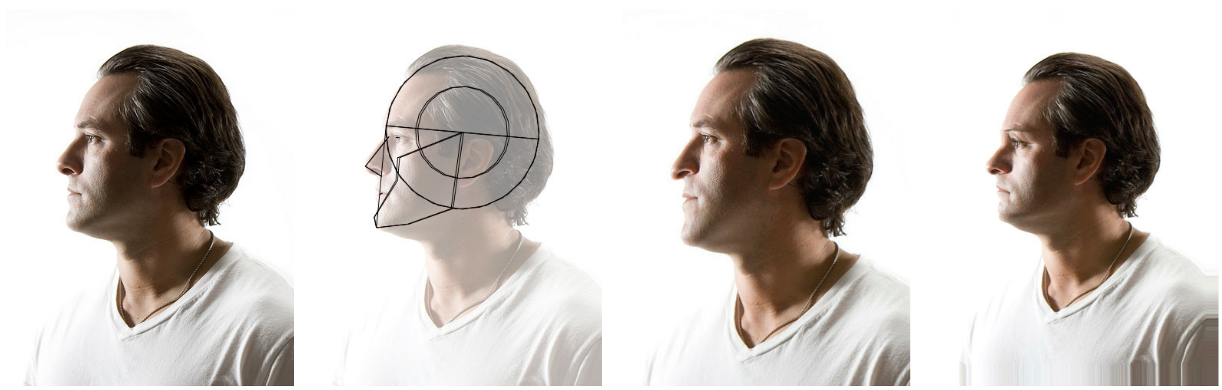

(a) Input Image (b) Fitted Morphable Guidelines (c) Warped face, variation 1 (d) Warped face, variation 2

Figure 1: *Input images are fitted with 3D morphable guidelines that allow for symmetrical and non-symmetrical warping of portraits facing any angle between profile and head-on via 2D image warping. Our morphable guidelines enable a wide range of image stylizations including manga-like warping and caricatures. Original image ©Ken 'kcdTM', 2009.*

Abstract

We present a system to help users achieve better face warping on 2D portrait images. Faces can be difficult to warp accurately because the rotation of the head affects the shape of the facial features. We bypass this problem by utilizing the Loomis 'ball and plane' head drawing method as a proxy structure. The resulting 'morphable guidelines' consist of a simple 3D head model. This proxy model can be reshaped by the user to mimic the positioning and proportions of a face in their input image. The vertices of the model act as deformation points for a 2D image deformation algorithm. Thus, the user can seamlessly transform the face proportions in the 2D image by transforming the proportions of the morphable guidelines. This technique can be used for both retouching and caricature warping purposes, as it is well-suited for both subtle and extreme modifications. Our system is advantageous over previous work in face warping because our morphable guidelines can be used on a wide range of head orientations and do not require the generation and reintegration of a full 3D model.

CR Categories: I.3.4 [Computer Graphics]: Graphics Utilities—Graphics editors;

Keywords: image editor, system, caricature, face, portrait, guidelines

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1 Introduction

We present a simple, user-friendly solution for altering facial proportions in photographs, such as those shown in Figure 1, via a morphable 3D proxy model and a standard point-based 2D image deformation algorithm. Our system creates accurate and convincing facial photo-manipulation results on photographs featuring a wide variety of head alignments, and is equally adept at both subtle photo manipulation and exaggerated caricature.

Point-based 2D image deformation is a conceptually simple but ubiquitous and indispensable tool in modern photo manipulation. In practice, it allows a user to select deformation points, i.e. points they would like to move to different locations, on their input image. The algorithm then interpolates all the unselected pixels to seamlessly transition between those deformation points, thus stretching or squishing the pertinent areas of the image to match. The resulting image is a selectively warped version of the input image. However, the fundamental simplicity of 2D image deformation can sometimes be a barrier to accessibility. The effective use of 2D image deformation depends largely on the correct initial placement of each deformation point. The more complex the structure, the more difficult it is to correctly place the points.

The inherent difficulties of 2D image deformation increase when the photo-manipulation subject is the human face – a subject that is a) difficult for a novice artist to render accurately and b) easy for the average viewer to determine as erroneous. The difficulty of correct placing deformation points on a face can be problematic when performing photo-manipulation, particularly on faces that do not directly face the camera and are thus asymmetrical on the 2D plane. Given that only a relatively small subset of prospective software users are educated in human anatomy and/or illustration, only a limited number of skilled users can use 2D deformation as an effective tool to manipulate faces.

Figure 2: *Caricature photo manipulation. An example of the type of modification we attempt to emulate. ©Rodney Pike, 2012.*

We address the issue of correct point placement on the face by using a simple 3D model as a framework for placing the key deformation points on the photograph. In doing so, we link the 3D space of the model to the 2D space of the photograph. All changes to the 3D model automatically reflect the perspective and foreshortening changes inherent to the original. Thus, the user can make 3D-space symmetrical changes to the 3D model and have the correct results appear in the 2D plane of the photograph. The proxy mesh gives users of all skill levels the inherent sense of three-dimensional construction that artists normally achieve through intensive training.

In order to lend authenticity to this artist-inspired approach, we have based our morphable guidelines on the Loomis ball and plane guidelines method [Loomis 1939], which is a commonly taught method of head construction among illustrators. Likewise, the controls used to manipulate the parameters of the morphable guidelines are based on those found in 'character creation' systems in commercial video games, which are designed to allow the average user to customize unique head models without regard to prior artistic training or experience.

Morphable guidelines are named after a similar system, the morphable model [Blanz and Vetter 1999]. We share the concept of a generic 3D model having access to a topologically consistent 'vector space' of faces, both realistic and stylized. However, morphable guidelines can produce similar results to Blanz and Vetter [1999] without multiple input images or the inclusion of a complex model.

The main contributions of this research are

- a user-friendly system for easier photo-manipulation of faces, regardless of artistic skill level,
- a methodology for transferring changes from the 3D space to the 2D space,
- a simpler and more economical alternative to previous methods of multi-angle face warping.

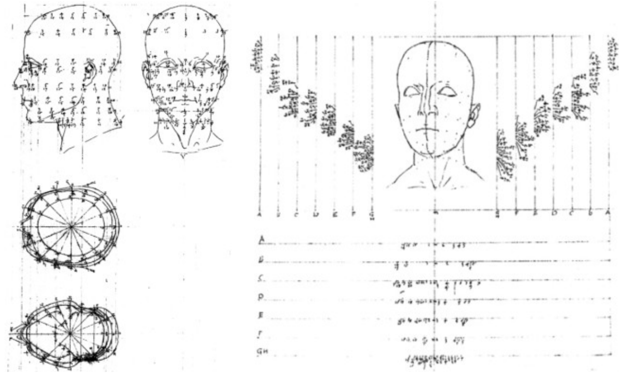


Figure 3: *Illustrations depicting techniques for handling perspective on the head, from Piero della Francesca's 'De Prospectiva Pingendi', circa 1480.*

2 Transcribing 3D objects on a 2D surface

The average person has a great deal of difficulty recording the visual world as he or she sees it. Overcoming the natural hurdles of perception and dexterity is a specialized skill set. Accurate drafting of 3D shapes requires superior development of visual memory and perception. A person who wants to convey realism through drawing must have a firm grasp on the way 3D objects interact with space. This can be difficult, depending on the 'camera angle' at which the subject is being 'viewed' or rendered.

For example, consider the human face. The human face is functionally symmetrical across the vertical axis. Thus, the easiest angles to draw a face from are the full-frontal view (two symmetrical halves) and the profile view (one half alone). However, views between the full frontal view and the profile view require the artist to draw both halves of the face, but in an asymmetrical fashion. Drawing one of these intermediate angles requires an artist to extrapolate the shape of each feature based on their personal understanding of the 3D shape of the head, cobbled together via a combination of memory and guesswork. This is as difficult as it sounds, and most artists spend years developing the sense through training.

The difficulty of maintaining proper proportions is significantly lessened when working off of a basis such as a photograph, especially when the medium at hand is the photograph itself. Photo editing applications allow a user to mould the 2D features of an image to their liking via warping tools. In the hands of a skilled artist, this can work out very well – modern caricature artists such as Rodney Pike (Figure 2) often work using a combination of 2D image deformation and digital painting. A novice artist, however, may have difficulty achieving good results without assistance.

The realization of dimensionally accurate, realistic drawing was a problem that was in fact solved through mathematical research. For example, the much-lauded advances in painting realism during the Renaissance period can be partially credited to architects and mathematicians, who codified the rules of vanishing point perspective during the 15th century. Books such as Piero della Francesca's *De Prospectiva Pingendi* (Figure 3) stringently codified the drawing faces affected by perspective in a methodological way. These techniques quickly proliferated through the artistic community and became part of the artistic canon. In other words, invention has always been a crucial part of artistic development.

2.1 Use of guidelines in art

In this paper, we use the word 'guidelines' in a literal sense. By this literal definition, 'guidelines' are lines that guide the placement of other lines. 'Guidelines' are preliminary structural drawings that delineate the composition of a finished piece of artwork, usually consisting of preliminary shapes such as ellipses and boxes. Guidelines help the artist to stay in control of the macro elements of their figure (anatomy, pose) while working on micro elements (outline, rendering). Art instruction using guidelines can be found in teaching materials spanning a wide variety of audiences and skill levels.

Guidelines can be used to assist the drawing of just about anything with a geometric component and are especially useful for drawing organic entities with movable parts, such as animals and humans. Basic figure drawing instruction trains the macro instincts via the ten-second pose exercise, which forces the student to draw a simple sketch of a live model within an extremely short timeframe before the model moves to an different pose.

Guideline methods for drawing human beings vary between artists, depending on their means of instruction and personal preferences. Complexity can vary from a few lines delineating the movement of the figure, to intricate assemblies of geometrical primitives. There are established guideline methods that simulate the body, as well as those that model the head. The Loomis ball-and-plane method is one of the latter [Loomis 1939].

3 Background

A typical method of producing warped faces uses the photograph as a texture on top of a generic head model. The most cited example of this technique in action is Blanz and Vetter's seminal SIGGRAPH 1999 paper, 'A Morphable Model For the Synthesis of 3D Faces' [Blanz and Vetter 1999]. The original morphable model utilized a 360 degree head-scan repository of 200 young adults as a set. By interpolating between the faces, the morphable model can mimic a large number of different faces. The reconstructed face is then combined back into the image. Such a textured model is complex, requiring a mapping between the image and the model, and resource-heavy, especially when the desired output only consists of a single image. A 2010 paper on whole-body morphing avoids the recombination issue by using points on the outlines of the model in a 2D image deformation algorithm [Zhou et al. 2010]. This is somewhat similar to our approach using a pre-simplified model.

The Active Shape Model (ASM) [Cootes et al. 1995] and the Active Appearance Model (AAM) [2001] are invaluable tools in the field of automatic feature extraction and face detection. As tools they are used to facilitate a large number of automatic face warping systems, as they automatically produce a set of points on the face that can be used as deformation points. However, these systems only perform satisfactorily on photographs of near forward facing head orientations. Additionally, the points on an AAM do not adequately describe the geometry of the face, and describes the face as a flat space defined by an outline of vertices. AAM does not take into account the symmetrical nature of facial features or assist the user with foreshortening cues.

Our method is heavily influenced by both caricature systems and portrait synthesis systems, which are two different approaches to the same stylization goal. Caricature systems use image warping to exaggerate features that deviate from the 'average' [Obaid et al. 2009], while portrait synthesis systems match individual facial features to the best match in a library of pre-drawn features [Chen et al. 2004]. We aim to create a framework that can facilitate caricature systems and improve portrait synthesis system results

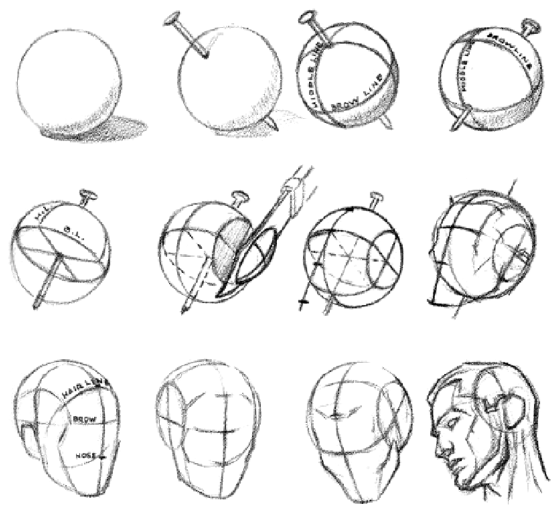


Figure 4: *Instructional illustration from Drawing the Head and Hands [Loomis 1956]. The centre point of the brow line is represented by the point where the horizontal and vertical arcs cross. Image ©Andrew Loomis, 1956.*

4 Morphable guidelines

In essence, the morphable guidelines are simple 3D models, similar to the structure produced by the ball and plane method. The vertices of the model act as a set of input points for image deformation.

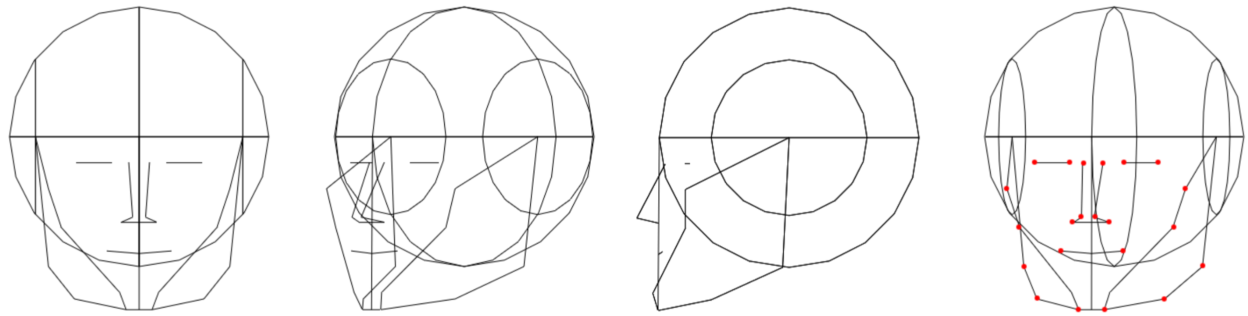
4.1 The ball and plane method

Our morphable guidelines (illustrated in Figure 5) are a 3D approximation of the Loomis ball and plane guidelines [Loomis 1939]. We aim to give the average user the discernment that an artist would normally achieve through the acquirement of skills, such as the effective use of guidelines.

We chose the ball and plane method, shown in Figure 4, for its popularity, flexibility and classic status among illustrators. American illustrator Andrew Loomis featured the ball and plane method in his instructional books [Loomis 1939; Loomis 1956], and his method has been used to teach proper face construction by instructors up to the present day.

The ball and plane method consists of two major parts; a ball representing the top part of the skull and a few lines that delineate planes and represent the jawline and lower part of the skull. The ball portion is bisected by perpendicular arcs, which flesh the circle into a 3D sphere and delineate the area between the brows. The arcs form a crosshair that succinctly shows which way the head is facing. The jawline consists of three curved lines – two representing the sides of the jaw and one representing the jaw.

The ball and plane method is common for two reasons. First, the ball and plane method produces a reasonably accurate three-dimensional model of the head, thus making complex angles and orientations simpler to draft. Secondly, the ball and plane method is generalizable to a huge range of different heads and faces. Thus, the ball and plane method provides a topologically consistent structure across the entire face vector. By reducing the structure of the skull to a few lines, a trained artist can easily draft the bone structure from which to build the desired face.



(a) Front view (b) 3/4 view (c) Profile view (d) Vertices

Figure 5: *Morphable guidelines in a series of different rotations.*

4.2 The 3D model

Our morphable guidelines are both more and less complex than guidelines produced by the ball and plane method. Generally the 'plane' portion of the analog method incorporates curves, but morphable guidelines are a framework for a system of vertices; thus, all curves and lines are simplified to a series of points. Some points have been added to delineate facial features.

The base shape of the morphable guidelines is a single stationary circle. It is delineated by two perpendicular 'cross' circles that pivot inside, which produces the illusion of a pivoting sphere. The remaining planes are described via a set of vertices (Figure 5d), connected by line segments. These planes pivot along with the centreline circles. The model thus appears to have a full 360 degrees of rotation around all three axes.

The principal controlling variable of the morphable guidelines is the radius of the circle. All model vertex coordinates are calculated via ratios of the radius. For example, the default measurement between the chin and the base of the nose is calculated as 1/3 of the radius measure, as with the default measurement between the base of the nose and the brow line. These proportions can be altered by changing the variable ratios that determine the size of each feature. A full list of important vertices and default ratios are listed in the appendix, under Table 1.

4.3 Proportion controls

Our morphable guidelines are generic across most faces. When the morphable guidelines are first generated by the system, the vertices are set with default proportions determined by a set of default variable ratios, as defined in Table 1. The variables are then adjusted by the user to produce the desired proportions. We call this process 'proportion warping'.

The key to the morphable guidelines control system is in the constraints. All basic proportion warping is constrained to be symmetrical on the 3D model – all changes to the vertex positions are reflected across the Y axis of the morphable guidelines. Thus, the user can always ensure that the changes they made to the face are geometrically correct in the 3D space, even though they are viewing the results on the 2D plane and moving the points.

If an asymmetrical pair of points is needed for a particular reason, such as a crooked smile, an additional set of asymmetrical controls alters individual ratio changes to either side. These asymmetrical controls are still dependent on the symmetric controls, so changes

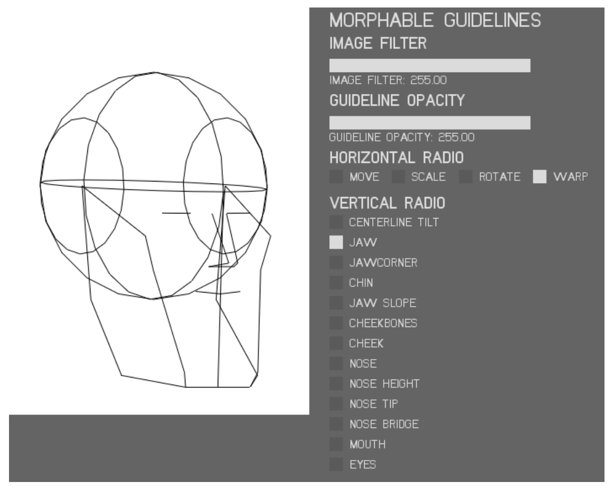


Figure 6: *A proportion warp involving only the jawline.*

made by the symmetric controls still affect the asymmetrical features. As these types of asymmetrical changes is commonly needed only for the mouth, we have limited the number of asymmetric controls in our implementation, though universal asymmetric controls could be incorporated into a more complete system.

5 System

Our system flow is presented in Figure 7. Our system takes a single portrait-style image as input and places a morphable guideline over it. The user adjusts the morphable guidelines twice: once to fit it to the face, and once to specify the new face. The system extracts a set of x/y coordinates from each of these configurations, providing a set of 'source' points and a set of 'destination' points. The input image and the source and destination points are then fed into a 2D image deformation algorithm. The image deformation algorithm produces the desired image by warping the corresponding pixels of the source points to the positions of the destination points, while interpolating the pixels in between.

In short, our system acts as a framework for more effective image deformation of the face. Our morphable guidelines enable easy placement of source and destination deformation points without requiring in-depth anatomical knowledge from the user.

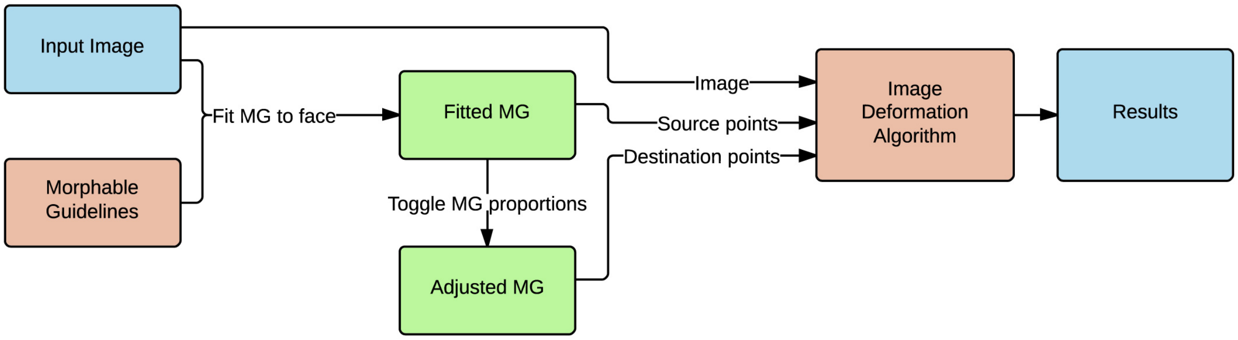


Figure 7: *An overview of the Morphable Guidelines system. The colour of the box background indicates the type of component: Blue indicates images, red indicates system components, and green indicates user inputs.*

5.1 Input Image

Unlike the analog ball and plane method, our system does have some criteria for an 'ideal' input image. Most of these criteria are determined either by difficulty of guideline fitting or by interference with our chosen method of image deformation.

We have designed the system to work with photographic portraits of humans. In this case, we define a 'portrait' as an image that a) has a human face is the focal point, and b) takes up a significant area of the image. It is possible to use a portrait of a cartoon character as the original image, as long as the proportions of the cartoonist's style are topologically consistent with the morphable guidelines. It is also possible to warp the face of a single person in a group photo or to create multiple morphable guidelines to warp several faces in a group photo, though the results are less predictable and the incidence of unwanted artifacts may increase.

The face should be reasonably unobstructed by hair, limbs or props, although some obstructions can be accommodated as long as absolute accuracy is not required. Higher resolutions (over 500 x 500 pixels) are ideal, as 2D image deformation is much more likely to cause artifacts in lower resolution images. However, many of the example images included in this paper are smaller than ideal.

We strive to emulate as many of the qualities of the ball and plane method as possible, and our system is able to handle a wide range of head facing angles. However, a head with more than 90 degrees of rotation on the X or Y axis is not strictly ideal, as most of the vertices of the model would be occluded by the back of the head.

A small degree of perspective in the photograph can be accommodated, but extreme up or down head facing angles can make the initial fitting stage difficult for the user.

5.2 Fitting stage

The 'fitting' stage of our system requires the most user effort. The user must resize, rotate and proportion warp the morphable guidelines to fit the input image and produce the 'source' coordinates of the deformation points. The correct placement of deformation points is crucial to achieving good results from this system. Ideally, this stage would be fully automated, but the face detection systems currently available do not handle the full range of rotation that our system can handle. In our experience with the system, a user can generally create a better fit than an automatic system. We address the logistics of an automated fitting scheme in Section 8.2.

(a) Input Image (b) Caricature warp

Figure 8: *An example of a photo manipulation that would be more difficult without the morphable guidelines. Original image ©Steve Evans, 2008.*

Our assumption is that morphable guidelines can be fitted easily onto any face that fulfills the input image criteria described in Section 5.1. Depending on the image, the ease of initial fitting can vary. The fewer axes of rotation present in the same head, the better – more complex rotations take longer to fit.

5.3 Adjustment stage

After the morphable guidelines have been properly fitted, the user should once again proportion warp the morphable guidelines to the desired parameters. This produces a set of 'destination' coordinates for the deformation vertices.

The actions taken in the 'adjustment stage' are completely determined by the goals and personal creativity of the user. For example, a user who wishes to make minor 'retouching' changes to the input image (such as heightening the cheekbones) could tweak the associated vertices slightly and leave the other controls untouched. On the other hand, a user aiming to create a caricature could enlarge or shrink large portions of the face to outlandish proportions.

Figure 8 provides an example of a portrait taken from a camera angle that produces a 3/4 view of the face. Normally, free hand warping this image would require tedious adjustment of individual deformation points on both sides of the face. With our system, the user enlarges the cheekbones, lowers the tip of the nose and exaggerates the tapering of the face by exerting those changes directly on the morphable guidelines.

(a) Input image (b) Morphable guidelines (c) 'Beautified' result

Figure 9: *A typical 'ulzzang' style beautification method, commonly used in South Korea. Note the tightened jawline/nose and subtlety enlarged eyes in the results on the right. Original image ©Frank Kovalche, 2011.*

5.4 Image deformation algorithm

Once the desired adjustments are made, the source and destination coordinates are fed into the image deformation algorithm along with the input image.

We use the moving least squares (MLS) image deformation method [Schaefer et al. 2006] as our image deformation algorithm. Moving least squares image deformation, a common method of 2D image deformation, operates over a triangular mesh. An implementation of this type of image deformation is accessible in Adobe Photoshop CS5+ as the 'Puppet Warp' tool.

MLS image deformation produces instant results when paired with our system. We use the simpler affine similarity deformation described in [Schaefer et al. 2006], instead of the rigid deformation. Affine similarity deformation facilitates smoother facial deformation and is slightly more efficient in runtime.

6 Practical applications

Our system produces attractive results across a wide range of applications. Morphable guidelines produces changes that are subtle enough for retouching (Figure 9) while also being powerful enough to make large stylistic changes such as the 'manga' illustration style (Figure 10) or caricature (Figure 11).

With a little modification, morphable guidelines could easily be implemented in existing photo editing software with 3D capabilities. Our methodology can easily integrate with existing caricature and beautification literature, possibly as a less automated but more versatile alternative to the popular AAM method [Cootes et al. 2001].

It would be easy to create a set of 'template' stylized morphable guidelines to use as destination points, thus allowing users to morph faces into pre-established styles such as manga. This is particularly effective when combined with a toon shading filter – Figure 10 shows an example that uses a toon-shaded input image [Winnemöller et al. 2006].

(a) Input image (b) 'Manga' style

Figure 10: *A face that has been morphed to typical 'manga' style proportions. Original image ©Mark Leo, 2008.*

Simple assisted image deformation algorithms for faces may be of use in medical fields such as orthodontics and plastic surgery, where before and after images are already in use. The predicted results of different procedures could be compared against one another during the decision-making process.

Lastly, there is no particular reason why this technique is only applicable to faces. A similar system could be applied to practically anything with a consistent structure, though the inexact nature of 2D image deformation is best suited to organic subjects.

7 Limitations of our system

The limitations of our system are mostly tied to the occasional difficulty of the fitting stage. Optimally, a morphable guidelines system should be able to detect the facing angle automatically, and perhaps the proportions as well. By combining our system with AAM research on face detection, we may be able to fit the guidelines with a reduced amount of user assistance.

(a) Source image (b) Caricature

Figure 11: *A face that has been morphed to capture the essence of the expression, á la caricature illustration. Original image ©Alvaro Frank, 2012.*

(a) Nose error (b) Nose error + guidelines

Figure 12: *When the nose should break the outline of the face, the image deforms in a manner that is topologically correct in 2D but incorrect in 3D. 2D deformation fails to produce a satisfactory result in this case.*

A major issue with 2D deformation can occur when certain features overlap in model space. For example, consider Figure 12a. In a photograph of a face at a 3/4 angle, all of the facial features will generally fall within the outline of the face as long as the proportions are realistic. If the user wishes to elongate the nose past realistic proportions, the nose may break the outline, thus affecting the topology of the image. An example of the error can be seen in Figure 12b. As 2D image deformation maintains 2D topology, it is impossible to make the overlap occur under these constraints. This error could be addressed in future versions through more rigorous preprocessing and the addition of 'cutout' portions of the image.

8 Future work

The morphable guidelines and the corresponding system shown in this paper are simple in concept and execution. Our novel system may benefit from a user study to test the ease of use and an automatic fitting stage. Additionally we believe the idea of morphable guidelines may be easily generalizable to morphing of other symmetrical natural objects. In this section we will discuss future applications of morphable guidelines.

8.1 User study

A natural evaluation of the morphable guidelines could include a user-based evaluation. A study would ideally include subjects with varying degrees of artistic training and consist of two sessions, one to evaluate of the ease and viability of the morphable guidelines system versus free hand adjustments of the same image and one to evaluate the artifacts made from using traditional two-dimensional image deformation versus our morphable guidelines system.

The first session would consist of two separate rounds of tasks, followed by a survey. In the first round, the subject would be shown an image of a cartoon character, then asked to modify a photograph to match the facial proportions of that cartoon character using free handed point-based two-dimensional image deformation. This would be repeated three or more times with different cartoon characters and photographs each time. In the second round, the subject would be asked to warp the same photographs to resemble the same cartoon characters, only using the morphable guidelines system instead of free hand. Both observational studies (to determine the number of movements or clicks used) and questionnaire would be used for evaluating this phase.

The second session would consist of a single round of tasks. The results of the first session, i.e. the free handed and morphable guidelines assisted warps, would be displayed together, along with the basis cartoon image. The subject would then be asked to rate both warps based on criteria such as accuracy and aesthetic preference.

8.2 Automatic fitting

The usefulness and user-friendliness of this system would increase dramatically with the addition of an automatic fitting stage. The addition of a robust face tracking package may even make it possible to warp faces in real time video.

Ideally, the fitting stage would be completely automatic, with the rotation and proportions being handled entirely by the program itself. Unfortunately, complete automatic fitting is not feasible at this time, as it requires more data than can be extracted from a single image via common methods of face detection. For this reason, contemporary systems that use photographs as skinning data for generic models usually require a certain amount of user input in order to confirm the locations of critical facial features.

On the other hand, partial fitting is much more easy to achieve and may still be of great use to the user. The correct rotation is determined largely by locating the point directly between the subject's brows and aligning the morphable guideline based on that point. If the correct scale and rotation can be achieved automatically, the user's burden is reduced to proportional warping only. This would most likely be much simpler to achieve using a typical Active Appearance Model [Cootes et al. 2001].

8.3 Modular morphable guidelines

The model of the morphable guidelines shown in this paper is carefully designed, but is arbitrary to the actual process of deforming the image. The model itself can be simplified or elaborated via the addition and removal of points. Thus, the system we present in this paper could be expanded to include customized morphable guidelines, as long as the customized models are symmetrical in nature. For example, our model includes an extremely primitive structure for handling eye location, but a user may prefer to create a much more complex structure to handle more elaborate changes to the eyes. This addition would greatly expand the usefulness of the system to a larger audience of users.

9 Conclusion

Above all, morphable guidelines are a tool that makes 2D face warping easier to achieve. Though it is completely possible to achieve our results freehand, it is a tedious process involving a large number of separate deformation points. Our system allows the user to concentrate solely on what they want to change about the face, instead of wrestling with the monotonous task of maintaining perspective and symmetry. It is a tool that facilitates creativity while maximizing quality and minimizing labour.

In conclusion, our paper describes a simple and effective way to warp faces in 2D images, unleashing the creativity of users and researchers to obtain a wide range of effects while maintaining three-dimensional symmetry.

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A Default morphable guideline parameters

Morphable guidelines are constructed using a set of ratios relative to the base circle radius r. When a set of morphable guidelines is initialized, it is constructed using these variables. The larger the value, the larger the deviation from the centre of the base circle.

The depth component (z) of features that lie on the centreline are calculated via the following function:

$$f(varH) = \frac{clineBD + (varH - faceH)(clineUD - clineBD)}{-faceH}$$

Variable set	Facial feature	Width (x)	Height (y)	Depth (z)
clineU	centreline (top)	-	-	1
clineB	centreline (bottom)	-	-	1.01
face	head (overall)	0.8	1.333	1
sidecircle	side circle radius	$\sqrt{1 - faceW^2}$	-	-
chin	chin (lower)	0.1	1.333	$clineBD$
chinU	chinU chin (upper)	0.15	$faceH * 0.9$	1.05
cheekbone	cheekbone	0.7	0.4	0.8
cheek	cheek	0.6	0.7	0.8
jaw	jaw	$faceW - 0.1$	1	0.05
jawcurve	jaw curve	0.5	1.25	$sidecircle$
eye	eyes	0.14	0.2	0.8
eyeS	eyes (spacing)	0.35	-	-
nose	nose (base)	0.14	0.66	$f(noseH)$
nosebridge	nose (bridge)	0.08	$eyeH$	$f(nosebridgeH)$
nosetip	nose (tip)	0.05	$noseH - 0.04$	0.17
mouth	mouth	1.01	1.01	$f(mouthH)$
mouthcorner	mouth (corners)	-	0.02	- 0.03

Table 1: *Default model variables and multipliers of radius r*