Scanner morphing simulation with image warping

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ABSTRACT

In this work, a new image deformation method based on a copy-art technique is described. This copy-art process involves the use of either a photocopier or a linear scanner with a motif in motion as the light bar sweeps by to create distortions. The new method provides an easy-to-use tool which is very intuitive and offers predictable results. This allows the artist to recreate the original copy-art process digitally. In order to define the transformation completely, the user has to specify three elements for the original image interactively: path, rotation and velocity. To get the final image, two methods can be followed: either to sample each line from the original image to the result image using forward mapping or to split the transformation into a grid. This latter approach will allow more control in the final result.

Keywords

Warping, morphing, scanner, deformation, images.

1. INTRODUCTION

Electrography or copy-art is a set of analog techniques involving the interaction of light and electricity to produce or transform images. Usually the device is a photocopier, and the process can be, for example, to make multiple-generation copies to obtain a dissolved image from the original. Another copy-art technique consists of moving the original image or object over the photocopier as the light bar sweeps by to create distortions from the original [Bern].

This analog distorting technique allows the designer or artist to create a large variety of distortions with a high level of expressivity. The artist can change the velocity of the original image while it is scanned (see Fig. 1) or can translate or rotate the image freely to obtain any distortion.

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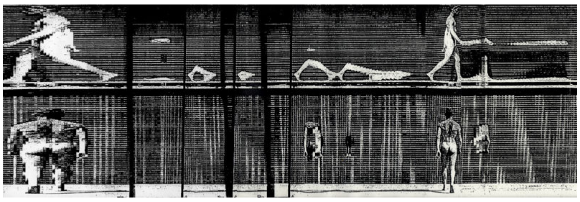

Figure 1. Work by J. Llopis and Rebeca Padin. 1992 Mide. Cuenca. [MIDE]

In this paper a digital equivalent method is presented. This method consists of deforming the original image following a line and some properties of it; all traced by the user. This approach offers some advantages: an easy-to-use interface, highly predictable results, the modification of the mesh after its generation and the possibility to repeat the complete process to apply the same transformation to a new input image. All these characteristics offer a new artistic tool to designers.

2. PREVIOUS WORK

Some methods have already been described to warp an image. These methods can be classified according to the type of transformation [Gom99]:

- Parameter-Based Techniques. This class of techniques, more than deforming an image or an object, is a modelling technique. A set of parameters, such as scale, twisting and blending, really defines the shape of an object. The modification of these parameters leads to a deformation of the original image or object [Barr84].

- Feature-Based Techniques. The user must provide a finite set of geometric features on the source image, and their corresponding counterparts on the target image. The deformation is defined by binding all the source and target features. A clear example is the two-dimensional field-based technique [Bei92].

- Free-Form Techniques. This group of techniques deals with a specification of the deformation based on coordinate systems, and using free-form curves (B-Splines, Bézier, etc.) to define the coordinate systems. The user must change the control points of the coordinate curves to define a warping [Ara95][Ara98]. The FFD (Free Form Deformation) has in [Seu96] a very good result.

- Hybrid Techniques: Some authors have combined the advantages of the previous techniques and have even developed a complete deformation environment to offer more flexibility [Mil02].

Scanner deformation

Regarding the deformation done by a linear scanner, some papers that can be found in the bibliography analyze this process in order to rectify it and obtain the original image [Wol95][Pil02]. The techniques used to unwarp the distorted image are based on an analysis process over the target, looking for known features from the source image.

In this paper a new method to warp an image is described. This method simulates the deformation obtained when an image is moved while it is being captured with a linear scanner. This method must follow these requirements:

- It must allow foldover (many-to-one mapping) of the source image. A section of the source image could pass twice or more times over the light beam when the user moves it.

- Highly predictable. The user must predict the resulting image with the deformation parameters provided.

- Fast. The definition and calculation of the deformation must be fast and easy for the user.

- Intuitive. The deformation method is based on a real analog distortion technique, so its definition must resemble the real process.

3. PROCESS DESCRIPTION

The process to be emulated consists of two elements: the capturing device and the input image.

The capturing device gets the input image by sweeping a light bar along its capturing area. It acquires the image line by line as the bar moves at a constant speed over the area. See Fig. 2.

The image to acquire is placed in the capturing area, usually remaining without movement. If the user needs, as a result, a distortion of this image, this image can simply be moved on this area as the light bar sweeps by (see Fig. 3). Depending on the movement, the user can obtain different results. For example, the image in Fig. 1 was done moving the original image parallel to the direction of movement of the light bar, allowing it to pass more than once over any portion of the original image. If the user rotates the original image, a completely warped image will be obtained.

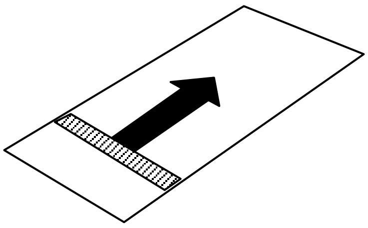

Figure 2. Capturing device: displacement of the light bar.

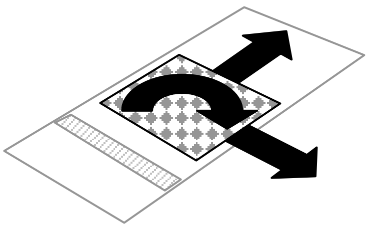

Figure 3. Original image movement as the light bar sweeps by.

4. DEFORMATION

Image warping

The transformation between the source and the final images is represented in Fig. 4. This image represents a transformation from the source space (the original image) to the target space (the final image) [Wol90]. As the target space is directly obtained as the light bar moves uniformly capturing lines from the source space, the final space is

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represented as a regular undistorted and orthogonal grid.

The source space represents the area of the original image to be mapped into the target space. As the original image can be moved and rotated, the original space must represent these distortions, hence the distortion of the original space. To obtain the final image from the original, the source space must be mapped on the target space. Note that with this definition, the source space can fold over itself.

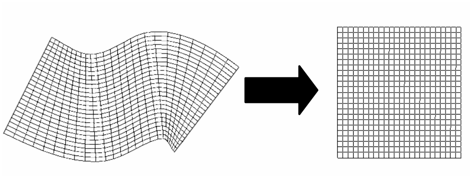

Figure 4. Scheme of the deformation system: original and target spaces.

Deformation definition

In order to define the deformation, the user must provide the movement of the original image to define the source space. This movement has been divided into three items: path, rotation and speed. These three items completely define the transformation that a user can create on a scanner.

4.1.1.1 Path definition

The first step involves the creation of a path that the light bar will follow over the image when it moves. In order not to distort the image, this path must be completely straight. To create a deformation, the user must create a curve by tracing some control points. These control points define a natural spline, and are pass points of the curve. This approximation has been chosen because of its simplicity of use.

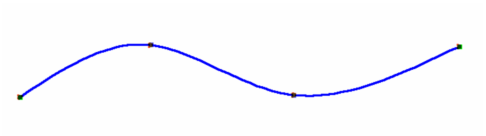

Figure 5. Path definition.

4.1.1.2 Rotation definition

Once the path has been traced, the preliminary rotations are calculated automatically as perpendicular to the trajectory (see Fig. 6-up). These rotations define the rotation of the light bar as it goes over the original image. If the rotation lines are all parallel the image is simply moved without rotation.

After the path is traced and the preliminary rotations are calculated, the user can freely define the rotation on every control point, simply by clicking and dragging the lines on every point (see Fig. 6-down).

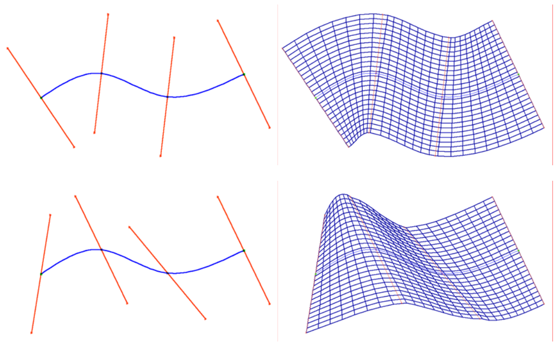

Figure 6. Rotation modification: preliminary rotations perpendicular to the path, and after user modification.

4.1.1.3 Speed definition

The third modification the user can define is the velocity, that defines the speed of the light bar over the original image. Defining a constant velocity makes no contractions or elongations of the central part of the image when is warped (the sides can change in size if the path traces a curve).

If the user defines different speeds along the path, the final image will show contractions or elongations, as shows Fig. 1.

To define the speed, the user must edit a bar diagram, where the vertical component is the speed of one segment in the path, and all the control points of the path are placed in the horizontal component. If the user rises one of the lines, he/she increases the speed of the corresponding segment between control points (see Fig. 7)

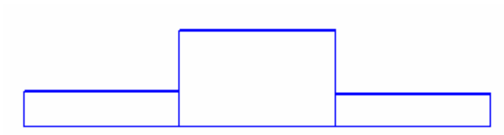

Figure 7. Speed modification: central segment has a higher velocity.

The user can see the result of the change in the mesh that represents the final transformation, as shown in Fig. 8. See below a description of how this mesh is obtained.

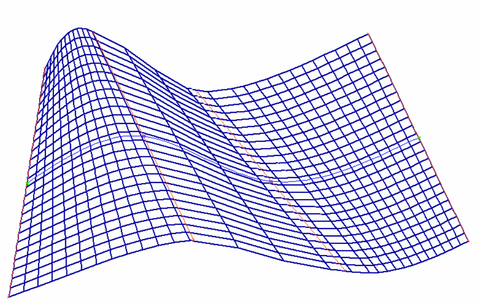

Figure 8. Mesh result of the speed modification.

5. MESH GENERATION

When the deformation parameters are completely defined, or during its definition, the user can see how the distortion will be with a deformation mesh that follows all the defined parameters: path, rotations and velocities. Through this mesh the user can foresee the final result image, because the mesh is constructed with the original space deformation.

As the final image is a rectangle, it is easy to divide this rectangle into a grid with constant spaces between rows and columns. If the source space is defined using a mesh with the same number of rows and columns, the final transformation is simply to apply every quadrilateral of the source mesh to every rectangle in the target grid (see Fig. 4).

To create this grid a two step process takes place: first, to calculate the subdivision of the path into the number of required parts following the speed definition, and second, to interpolate the rotations between parts.

Path subdivision

The calculation of the subdivisions is trivial when the velocity is constant along the path, every segment is simply the subdivision of the path length into the number of required parts (see Fig. 9a).

If there are velocity variations along the path, the parts with higher velocity must have fewer and larger segments, whereas the low velocity parts must have more and shorter segments.

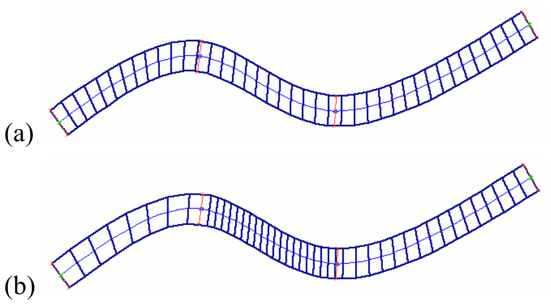

Figure 9. Constant speed path subdivision (a) and variable speed (b).

In order to obtain this result, the subdivision of the total length into the segments is done using the 'virtual length' of the path, not the real length, and the resulting segments are repositioned on the real length of the path. This virtual length is the result of multiplying the real length by the velocity relation. See Fig. 10.

In the final mesh, as every source quadrilateral is mapped on a quadrilateral of the target grid, the more speed it has the bigger source quadrilaterals are, obtaining a final image with a smaller sampled area as the scan of that area takes less time. See Fig. 1 and Fig. 10.

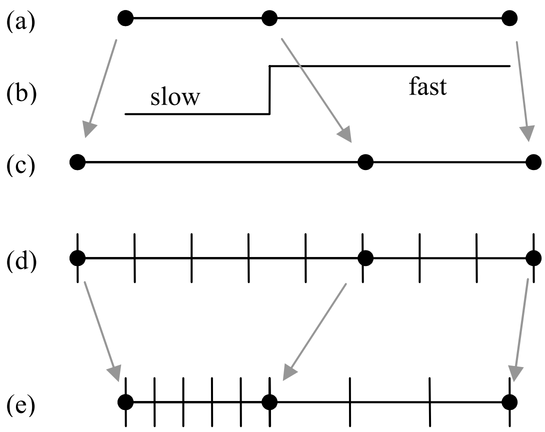

Figure 10. Calculation of the segments along the path: (a) real length path, (b) speed, (c) virtual length obtained from the speeds, (d) segments of constant length in the virtual path and (e) remapping of the segments on the real path.

Rotation interpolation

Once all the segments in the final path have been defined, the rotation of the segment to define the final path is linearly interpolated between the rotations defined by the user (see Fig 11).

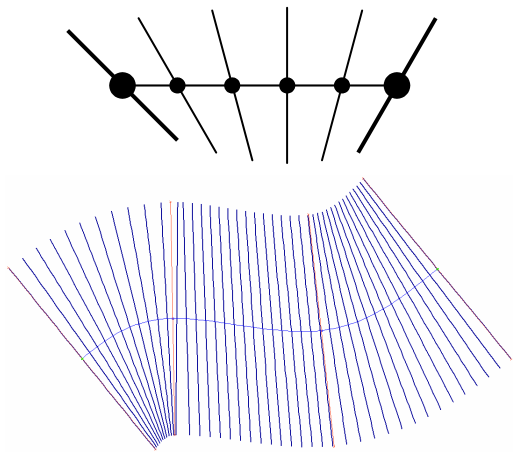

Figure 11. Interpolation of the rotations between the lines defined by the user.

The final interpolation lines do not need to pass exactly through the control points, as shown in Fig. 12. If the final segment subdivisions do not match the control points, the obtained rotation is interpolated between the closest control points.

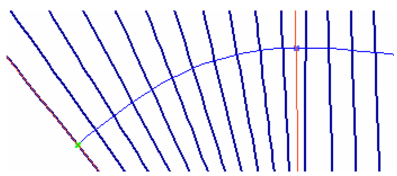

Figure 12. Red line defined by the user, blue lines are interpolated (detail from Fig. 11).

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6. SAMPLING

After the transformation is defined, there are two methods for obtaining the final warped image: quadrilateral subdivision or scanline sampling.

Quadrilateral subdivision

The image transformation can be defined as the mapping from the source to the target spaces (see Fig. 4). As the mesh that defines completely the source space is already done, it is straightforward to map every quadrilateral from this mesh to the regular grid in the target space.

There are two main techniques to map a quadrilateral to another quadrilateral: bilinear and perspective [Hec89]. Due to the particular characteristics of this work, as the quadrilaterals are contiguous and can differ in size and shape, the bilinear mapping has been chosen (see Fig. 13).

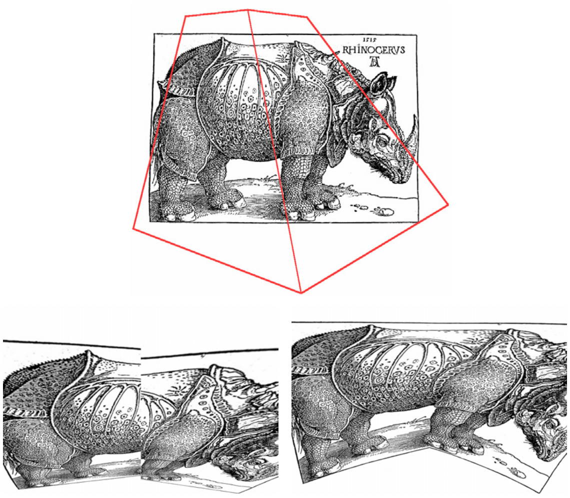

Figure 13. Up: original quadrilateral subdivision. Down-left: perspective transformation. Down-right; bilinear transformation.

The final mesh can have some concave quadrilaterals, but the bilinear transformation can manage it without problems. For example, if the source quadrilateral crosses itself, defining a singular point, the bilinear transformation simply applies that point from the source space to one line in the target space (see Fig. 14).

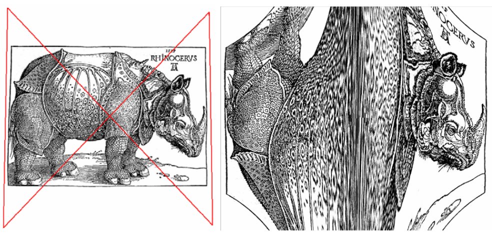

Figure 14. Bilinear concave deformation: original quadrilateral (left) and bilinear transformation result (right).

Scanline sampling

In the original space the transformation is defined by sweeping a straight line, so it is possible to use another mapping method that takes advantage of it. In this method, every line from the source space can be directly mapped to the target space.

A number of lines equal to the number of vertical pixels in the final image must be generated to define the source line distribution to be sampled, with the same algorithm described in Section 5 (Mesh Generation). The obtained lines are directly mapped into every pixel row of the final image. See down part of Fig. 11 for one possible approximation of the source lines to be sampled.

This sampling process approximates how the real analog technique works.

7. RESULTS

This technique can lead to very expressive images, as shown in Figures 15, 16 and 17.

Artists can now add this new digital technique to obtain copy-art simulated images, and it provides a very easy-to-use and intuitive way to warp images.

8. FUTURE WORK

Transformation definition

This technique can easily be extended to the use of straight sweeping lines to any arbitrary sweeping curve. The definition of the deformation would add the possibility of edition of the current lines to transform them into any curve, and the mesh and sampling calculations would interpolate between lines. If the new process is extended to curved lines, the scanline transformation must map a curved line from the source space to a straight one in the target space.

This improvement can lead to a general warping method, similar to the one described in [Lin05].

Mesh modification

The calculation of an intermediate mesh between the parameter specification and the final image warping generation can give the possibility to add more modifications to the transformation. If a set of mesh modification tools is offered to the user, some minor or major changes in the mesh would be applied after the mesh generation, giving the user more possibilities.

Use on animations

In this paper the technique is used on a static image, but if an animation or video is used, it can lead to interesting effects, for example a simulation of a photo-finish camera. See [Gol04], [Davi] or [Davie] for more details.

9. ACKNOWLEDGMENTS

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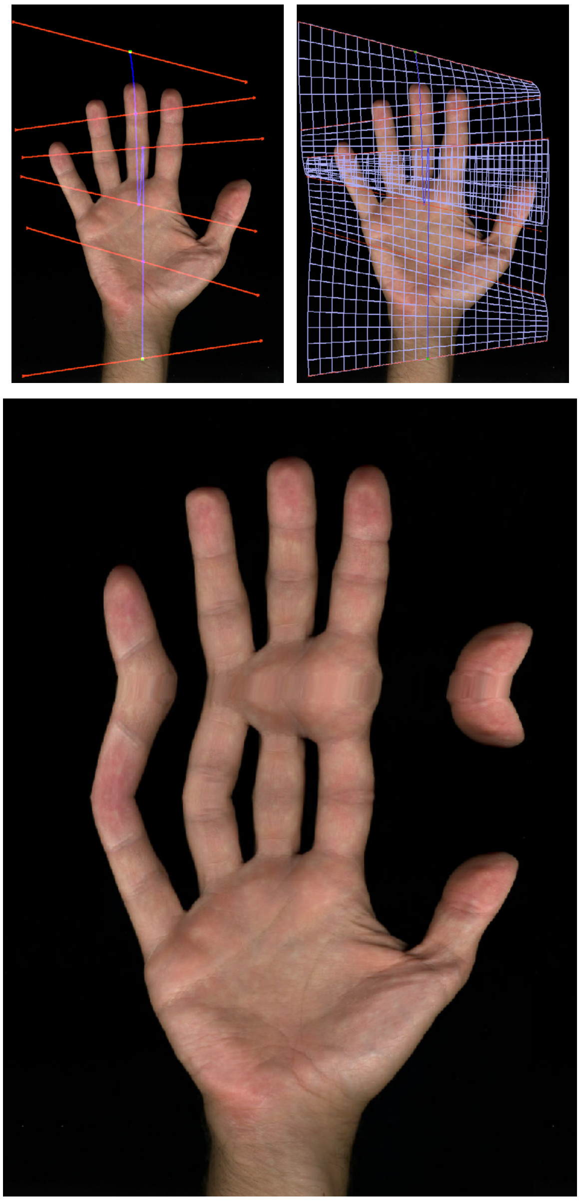

Figure 15. Simple deformation of a hand. Up-left: traced lines, Up-right: mesh, Down: resulting image.

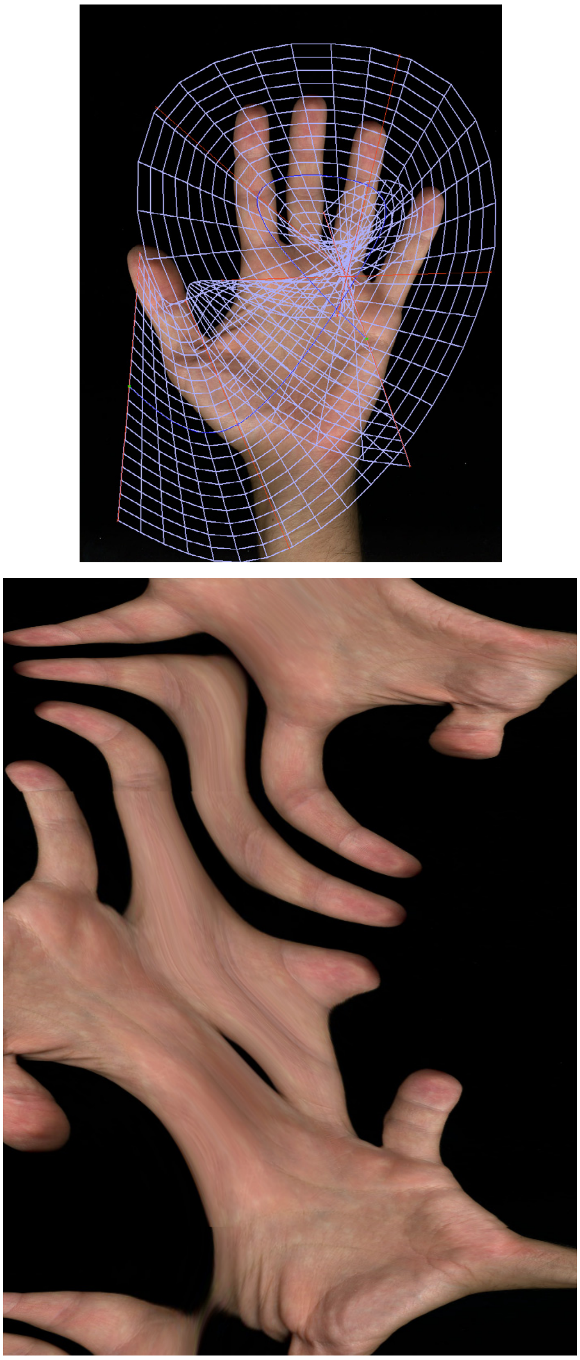

Figure 16. Complex deformation of a hand.

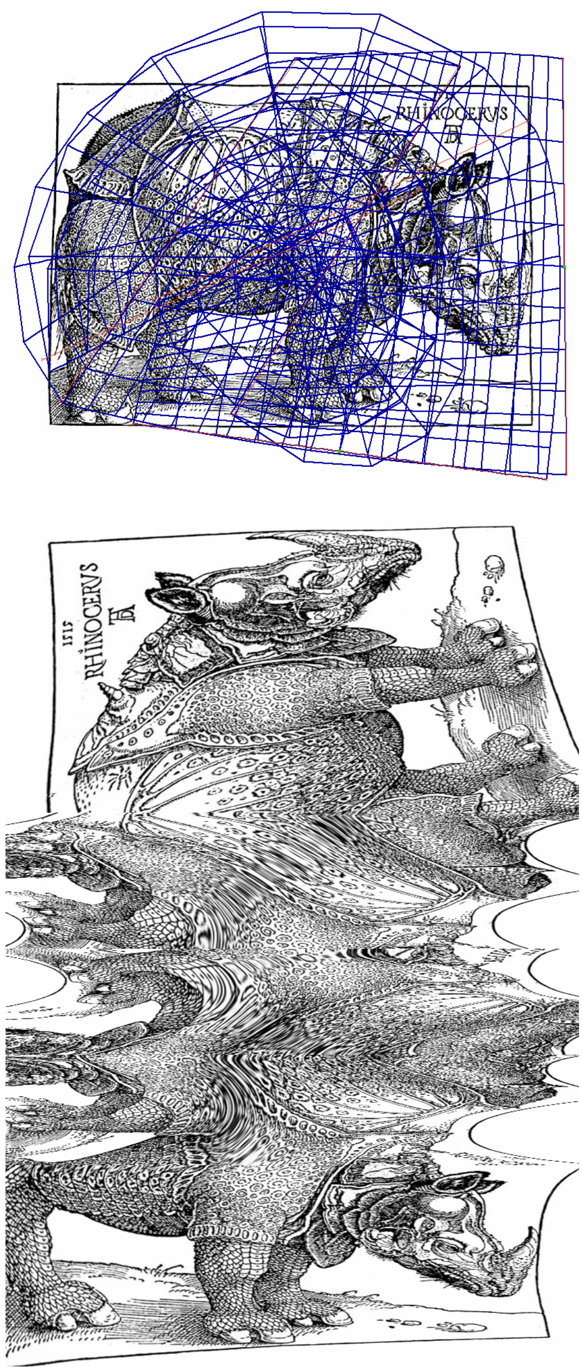

Figure 17. Complex deformation of Albrecht Dürer engraving ‘The Rhinoceros’, 1515.

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