Reflection art: A drawing interface

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Abstract

Artists that create mirror anamorphosis usually relies on the principle of trial-and-error and manual mathematical calculations. they have to draw a deformed image on the surface to get the desired reflected image on the mirror object. A drawing interface to make this kind of art does not exist currently.

In this paper, we make a suitable drawing interface that satisfies the needs of artists. We analyzed the common needs of artists and propose methods to address them efficiently. Anyone can easily produce mirror anamorphosis with our tool as long they provide the mapping between surface image and reflection image.

1 Introduction

By using an object that reflects the surface and if observed from a specific viewpoint it reveals an undistorted reflection of the surface; a mirror anamorphosis. In West Bromwich, England, at a bus station lies Anamorphic Portico which is made by local sculptor Steve Field (Figure 1).

A few tools exist for showing mirror anamorphosis, such as using a cylindrical mirror widget [1] or using an iPad screen to detect the position and rotation of the cylinder[2]. Currently, most artists rely on the principle of trial-and-error and some of them make use of mathematical calculations. Due to this, it takes a long time to draw the surface image and have the correct reflection. It is also important to know which object they use. There are many different objects that can be used to reflect the image. For example, a cylinder can be placed in the middle of the surface to reflect the art.

To make this kind of art can take a lot of time and it is not easy to make one without the appropriate tools. There are not many tools for this. For example, a drawing interface to make this kind of art does not exist currently. With a drawing interface artists, can not only make the reflected image but also hide this reflection in a vastly different surface image, rather than simply stretching out the reflection onto the surface.

István Orosz has specialised in mirror anamorphosis and has created a few images where both the reflection and the surface image are completely different art. One of his known creations is the Mysterious Island, where the surface image is a seashore but the reflected image is a portrait of Jules Verne (Figure 2). With a proper drawing interface, creating these kinds of art becomes a lot faster and easier.

In this paper, first, the common needs of artists to create a mirror anamorphosis are explained. Second, the implementation of the tools is presented. Third, the results of the interface are shown. The end of the document will cover the responsible research before concluding and outlining future work.

Figure 1: Anamorphic Portico. [3]

Figure 2: The Mysterious Island. [4]

2 Related work

There are a few works done on mirror anamorphosis. Research on creating mirror anamorphosis with cylindrical mirror has been done using mathematical calculations [9] [10]. Using those mathematical calculations you can create a mirror anamorphosis with any cylindrical mirror. To create a mirror anamorphosis with different shapes of mirrors is a challenge. Francesco de Comite proposed a way to create a general procedure [11]. It is not completely automated but it does not take a lot of time to work with any mirrors.

A way to display mirror anamorphosis, Suga, C., & Siio, I. created a tool to display it with a cylindrical mirror [2]. By using an iPad and two touch pens, an image can be seen in the mirror. The mirror can be rotated 360 degrees. The surface image and reflected image changes depending on the rotation of the mirror. This can be used to show a mirror anamorphosis art from any direction.

Those works are great for creating new simple mirror anamorphosis art and displaying them. Creating a more complex art such as the Mysterious Island [4] can not be done easily.

Kim, T., Ahn, S., & Lee, S. made a tangible interface for drawing Mondrian[5]. The user can create their own digital artworks with it.

A drawing app focused on children made by Yadav, S., Chakraborty, P., & Mittal, P. for their study [6]. They made simple features such as multi colours, 'undo' and 'redo' buttons. The older the children, the more features they use of this drawing app.

Laura Turón made a video of her Anamorphic drawing workshop where she explains how to make mirror anamorphosis manually [7]. The drawing interface automates this process in the background.

Those works can be used as the basis for a drawing interface. To make mirror anamorphosis, more features are needed. it needs more automatisation and support for mirrors of any shape.

3 Problem definition

This section is about the main challenges of creating tools in the drawing interface that can satisfy the common needs of artists. This research aims to find and make a drawing interface that satisfies artists to make a mirror anamorphosis. Artists have common needs and this research aims to fulfil those common needs because there is not any drawing interface that is sufficient to do that. The main question for this research question is: What are the needs for artists to make mirror anamorphosis in drawing interface? To answer this question we will use the following challenges as sub-questions:

1. The first challenge is to allow the user to use any mirror object. The user should be able to provide their mapping and make a mirror anamorphosis.
2. The second challenge is supporting colour and shape distortions. The drawing interface should be able to automatically convert colour and shapes.
3. The third challenge is to allow the user to work on both surface and mirror object. The drawing interface should automatically convert surface image to reflection image and vice-versa
4. The fourth challenge is to minimise the input as much as possible. The user should be able to make art more efficient and faster than without the drawing interface.

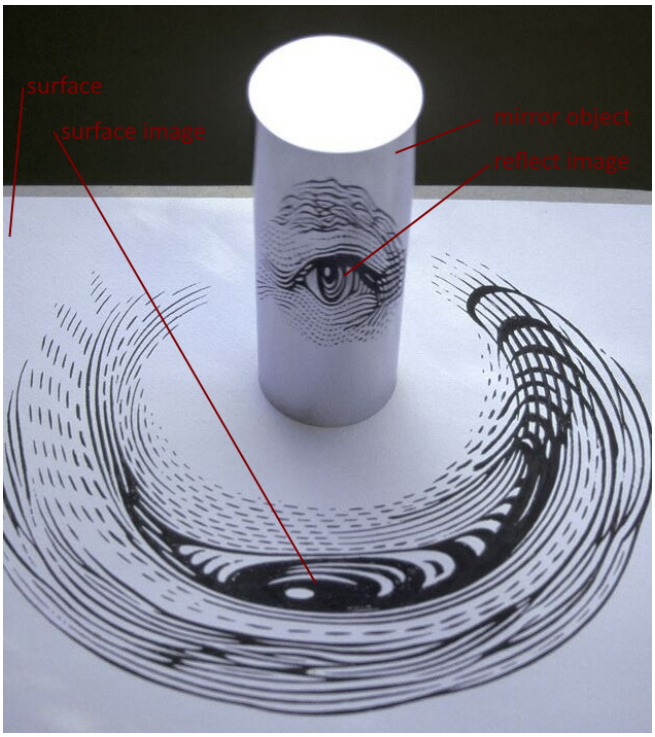

Figure 3: object names [8]

3.1 Mirror object

The object reflects the image from the surface. Not every object is suitable to be used. The object needs to be able to reflect the surface and it also needs to be able to show a distorted image compared to the surface image with a certain view.

There are three basic types of mirrors: plane, convex and concave (Figure 4). A plane mirror will reflect the image without distorting it. The reflected image on the mirror is the same as the image on the surface. A convex mirror distorts the image where the reflection is reduced in the centre and magnified in the centre. A concave mirror does the opposite of the convex mirror; the image is magnified at the centre and the magnification decreases moving away from the centre.

By using and/or combining those 3 mirrors you can create a reflection image that is different from the surface image. The most known example for creating mirror anamorphosis is using a cylinder. The cylinder is a convex mirror where the surface image is distorted in a horseshoe shape, causing it to be stretched out.

Figure 4: The three types of mirrors. [12]

To know exactly what the user uses as the mirror object we ask the user to provide the mapping. The input of the user is the mapping of surface image to reflection image and vice-versa. The mirror is usually a different resolution than the surface. To know the resolutions, the user provides two different mappings. The first mapping is the larger resolution to lower resolution. The resolution here is the size of the image. This mapping is 1:1 with a larger resolution to lower resolution (Figure 5). The larger resolution should be integers as the size of the image is larger, while the lower resolution should be a float. The decimals in the float show that the pixel on the larger resolution only partially fills the lower resolution. The pixel on the larger resolution should not fill a whole pixel on the smaller resolution.

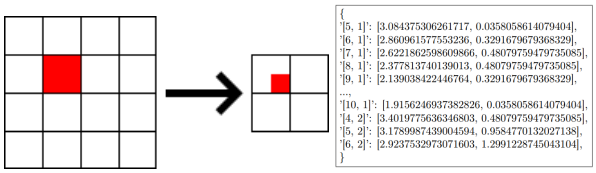

Figure 5: Mapping: larger resolution to lower resolution.

For the second mapping with the lower resolution to larger resolution, the mapping is 1:x, x is an array of pixels from the larger resolution to the lower resolution (Figure 6) with percentages that tell the contribution of that pixel to the lower resolution pixel. A pixel on the smaller resolution is a blob on the larger resolution. This means that we need to know which pixels on the larger resolution it uses and how much space it uses.

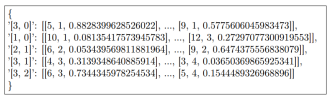

Figure 6: Mapping: lower resolution to larger resolution.

3.2 Colour and shape distortion

The object can be any colour and shape. This means that the difference in resolution of the surface and object can be problematic. Certain colours and shapes on the larger resolution will not be seen anymore on the smaller resolution.

The difference in colour can be found between the surface image and the reflection image. If the object is convex then the difference in resolution can be so significant that certain colours blend on the object making it hard to decipher the original colours. In contrast, if the object is concave then areas will be stretched out on the object. Another instance that can happen is that the object has a colour or is tinted. This means that the colours on the surface will be different on the object. For example, a red mirror will have a red-tinted reflected image compared to the surface image.

With the provided mapping we can calculate the pixels on the surface that accounts for a single pixel on the reflected image.

Figure 7: Reflection with a red mirror. [13]

Shapes on the reflected image can be different from the shapes on the surface image due to distortion. This means that if you have a square on the surface then it can be an oval on the object. Therefore if you want to have a certain shape on one then you might need to work with a different shape on the other.

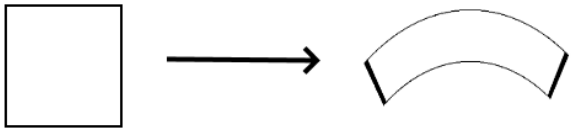

Figure 8: Distortion of a rectangle.

3.3 Drawing surface

The artist can have a different preference for a drawing surface. Most artists will draw something on the object and the surface can have a stretched-out image or a condensed image. If they want to have completely different art on both the surface and the object then the artist should be able to draw on both of them.

On the object is usually where you can see the original art created by the artist. The artist can create the art they want without any distortions on the drawing interface. It should be the same as creating art without a mirror.

The surface image is the distorted image of the reflected image. This means that while drawing on the surface the artist can hide colours and shapes that will not be shown on the object. Such as areas that are not shown on the reflected image on a certain viewpoint.

3.4 Minimise input

An artist should be able to start as soon as possible with their art on the drawing interface. This means the input from the artist should be minimised to be more efficient and faster than manual drawing. The only inputs required should be the important ones such as the mapping of the object and surface.

The surface should be large enough to show the reflected image of the object from a certain viewpoint. Some areas of the surface will not be shown on the object and the artist can make use of those areas to draw something that is not shown on the object.

4 Your contribution

In the following section, we tackle previously mentioned challenges and implement a solution in the drawing interface.

4.1 Real-time conversion

The drawing interface can generate the mapping for cylindrical mirror objects with given dimensions. The user can also use a custom mirror object but needs to provide the mapping for the drawing interface. Using this mapping we can provide real-time conversion during the drawing. If the user draws on the surface then it will also automatically convert it to the mirror object and vice-versa.

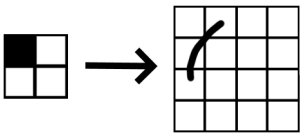

Figure 9: pixel conversion to blob.

4.2 Colour blend and shaping

Using this kind of mapping we can also get the right colour for conversion. One pixel in the smaller resolution is made of several pixels of the larger resolution. This means to get the right colour of that one pixel we need to average the pixels. With the percentages in the mapping, we know the weights of every pixel in the larger resolution to get the correct colour for this pixel in the smaller resolution. This is the same as down-scaling. For instance, take a checkerboard in black and white only. Downscale the image to 50% and you will get a grey image. s

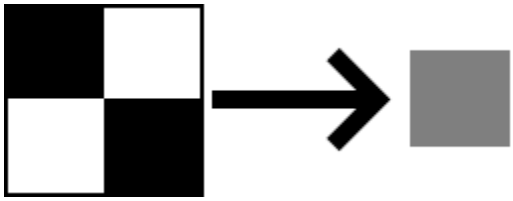

Figure 10: Checkerboard down scaled to 50% turns into a grey image.

For the other way around we need to fill the pixels with the percentage in the mapping of the pixel. This means that you will get a blended colour of the pixel with the background. This also works with overlapping areas of blobs because of the mirror. The colour on the pixels that overlap will have a blended colour (Figure 11).

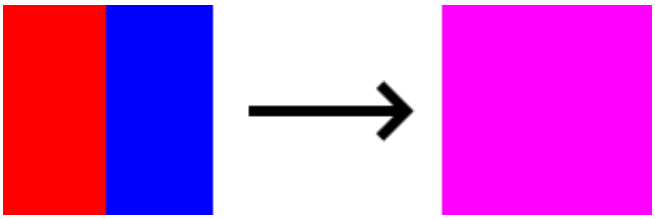

Figure 11: colour blending

The reflected shape is different after drawing on the mirror or surface. A straight line on the object can be a curve on the surface. The interface will automatically transform the shapes the user draws from one to the other. This means any kind of shape can be made.

4.3 Drawing

The drawing interface accepts drawing on both the surface and the mirror object. By having the two corresponding mappings you can draw on any of the two and it will automatically convert in real-time to the other image. This includes automatic colour blending from converting.

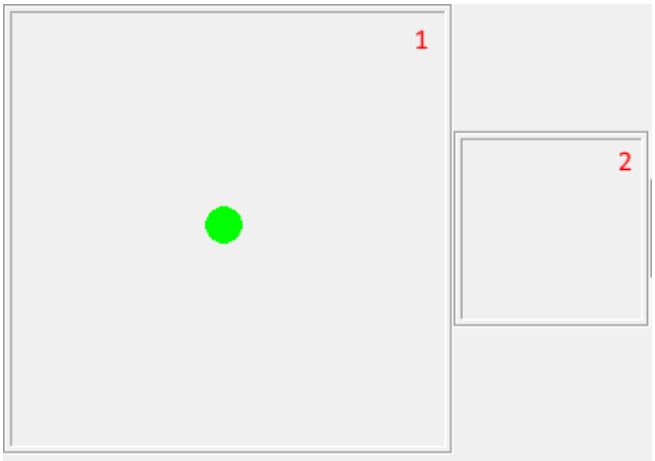

Figure 12: (1) The surface (2) The mirror object

Some areas of the surface are not in the mapping. Those areas are outside of the reflection mirror and can be used to make the art richer. The artist can create an image with a hidden art that can only be seen in the mirror. The drawing interface provides extra space for the user to create such art.

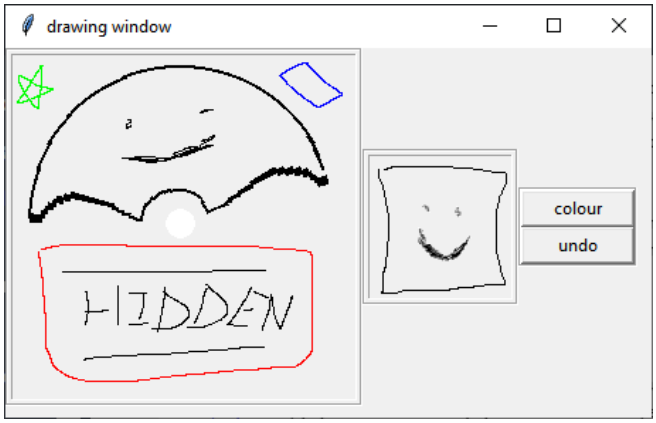

Figure 13: Surface drawing with text and shapes that are not shown on the mirror object.

4.4 Manual input

Most of the work can be done automatically by using the tools provided by the interface. Only little manual input is needed from the user. First, the mapping that is used for the drawing. Second, sometimes they want a coloured mirror and the reflection of the image from the surface will have a coloured tint. The drawing interface will automatically calculate the colour that should be on the mirror. The artist can then draw freely and pick any colours to make their art. But the colour of the mirror object can limit the colours that can be seen on the reflected image.

5 Results

In this section, we show the results of the implementations for the drawing interface.

The goal of this drawing interface is to not only show theoretical results but also practical results. This means that every sub-research question is answered with an implementation in the drawing interface.

5.1 Usable objects for mirror anamorphosis

To solve the first challenge to allow the user to use any mirror object, We create either a mapping for cylindrical mirror objects or let the user provide the mapping. This approach of mapping is better than a 1:1 mapping. In Figure 14, we can see what happens if you use a 1:1 mapping from a lower resolution to a larger resolution. To fix the empty gaps between the pixel, an upscaling algorithm is needed. However, the mirror object can be any shape. This means we cannot say for sure which pixels should be part of the green pixel or the blue pixel. With our approach of mapping, you can see exactly which pixels contribute to one pixel. There should be no issues with this upscaling problem.

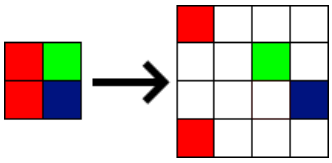

Figure 14: 1 to 1 mapping with different resolution.

5.2 Colour and shape distortion

For the second challenge to support colour and shape distortions, we can use the same mapping. The percentage in the mapping tells us how much of a pixel in the surface contributes to one pixel. This is used to calculate the correct colour of that pixel. The colour of the mirror is included in the calculation of the colour of that pixel.

Any shapes drawn on the mirror are different from the shapes on the surface. This is because none of the lines in the mapping is the same. With a cylindrical mirror, you can see that some straight lines in rectangles are transformed into curves.

In Figure 15 and Figure 16 the distortions with the drawing interface can be seen. Both colour and shape distortions can be seen. A standard mirror will have the same colours on both sides. A red coloured mirror reflects blue lines as black but can show different tints of red.

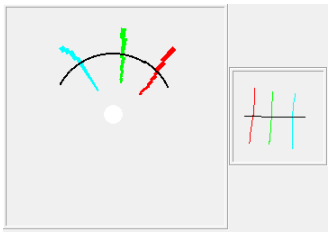

Figure 15: Colour reflection on a standard mirror.

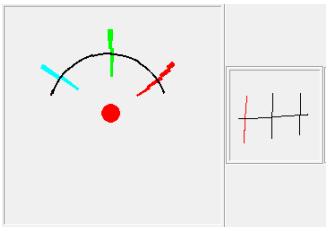

Figure 16: Colour reflection on a red mirror.

5.3 Drawing preference: surface, object or both.

Thirdly: for the challenge to let the user work on both surface and mirror object: we made it possible to draw on both the surface and object.

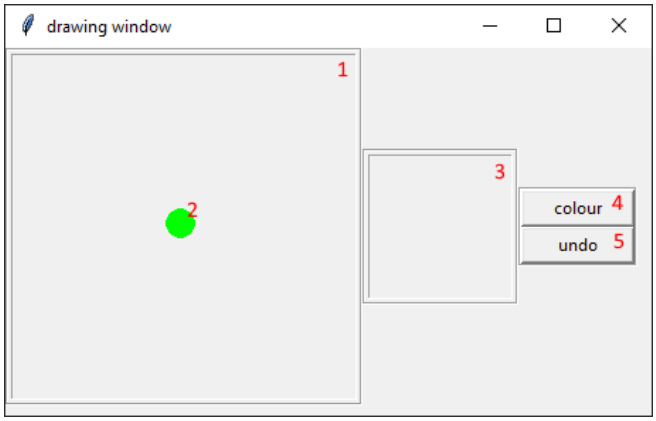

Figure 17: (1) The surface drawing (2) The mirror object (3) The mirror object drawing (4) Change drawing colour (5) Undo last change

5.4 minimise the input of user

Finally: minimising the input as much as possible for the drawing interface. We create an interface that only asks for necessary inputs from the user. This means in the main menu of the interface we ask the user to input the mappings and the colour of the object.

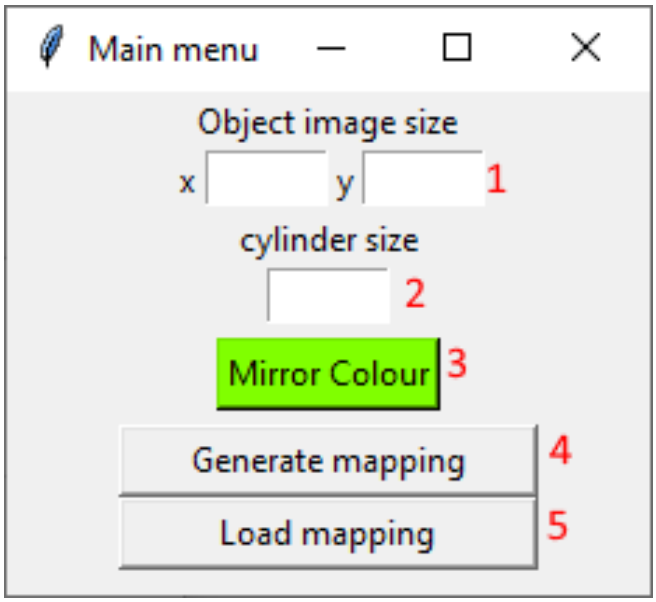

Figure 18: (1) The size of the mirror object drawing area (2) Cylinder size if mapping is not provided (3) The colour of the mirror object (4) Generates the mapping of cylindrical mirror object (5) Load mapping that is provided by the user

For the drawing, we created another menu where the user can draw on the surface and object. The conversion of the drawing is done automatically and in real-time. The user can also change the colour and automatically convert the colour if they draw on the mirror.

In both figure 17 and 18, the interface can be seen with only necessary inputs from the user. Conversion from surface to object and vice-versa is done automatically. Converting colours with the colour of the mirror is also done automatically.

6 Responsible Research and discussion

This section contains information about the research environment and reproducibility of the research.

The code used in this research is available on gitlab[14]. This means that all the implementations can be used to create the same results.

6.1 Limitation and improvement

The drawing interface is implemented using Python. Some algorithms that are used in the drawing interface, for example, calculating the mapping for cylinders can take a lot of time if the dimensions are really large. The time it takes to load given mapping from the user can also take some time.

The algorithm behind calculating real-time conversion can also be improved. Implementing points in a line algorithm could vastly improve the speed of calculation. Making small changes is unnoticeable, but by creating fast long lines some delay can be noticed.

7 Conclusions

This section contains the summary of the research questions, implementations and answers.

The main question for this research question is: What are the needs for artists to make mirror anamorphosis in drawing interface?? To get an answer to these questions, several sub-questions based on the needs are made. The sub-questions are the challenges to solve the needs of the artists. First, the drawing interface needs to work with any mirror object. To solve this challenge, mapping is used to convert the image from the surface to the mirror object and vice-versa. The mapping is provided by the user. An object is valid if there is a mapping for it. The mapping depends on the resolution. The mapping for larger resolution to lower resolution is 1:1. While the mapping for the lower resolution to larger resolution is 1:x. This means that a pixel on the lower resolution is a blob on the larger resolution.

For the following challenge: ”The drawing interface needs to support colour and shape distortions.”, we also use the same mapping. For every pixel in the lower resolution to larger resolution mapping, it contains information of percentage contribution to a pixel to the lower resolution. This means that we can calculate the appropriate colour with those percentages.

Any shapes can be made with this mapping too. A shape on the surface can have a different shape on the mirror object. A curve on the surface can be a straight line on the mirror object.

Next is the challenge: ”The artist can draw on the surface and mirror object.” Every artist can have a different preference for drawing. To support every preference, the drawing interface lets the user draw on both the surface as well the mirror object.

Lastly, ”Minimise the input as much as possible on the drawing interface”, is solved by having the interface with

only necessary inputs. The user only needs to provide the mapping and the colour of the. Then the user can start making their art. If the user draws on the surface then it will automatically convert the drawing to the mirror object. This also happens vice-versa.

With those answers, we can conclude those are the needs for the artists to make mirror anamorphosis. The drawing interface provides the necessary tools to create mirror anamorphosis. The user can create mirror anamorphosis art faster and easier with it.

8 Future works

In this section, we look at possible extension for the drawing interface.

8.1 Spotlight

By using spotlights we can hide parts of the mirror object. This means that only the part that is in the spotlight can reflect the image on the surface. This means that the mirror object can be of any size. The spotlight can also have a specific colour. Then only certain colours can be seen on the reflected image. This is mostly the same as having a mirror with a colour. The only difference is, is that if both the spotlight and mirror is not white, then nothing can be seen. With this, you can create an image with different colours and with different spotlight colour you can see different hidden images. For example, if you have a white mirror object and the surface consist of two colours: red and blue. Depending on the colour of the spotlight, only one of the two colours can be seen.

8.2 Metamerism

Metamerism can also be used in mirror anamorphosis. This means that certain colours can appear to be the same under certain illumination. The surface can be seen as two different colours while the mirror object is seen as the same colour. To achieve this, an implementation of lighting needs to be made. The mirror object colour can also be used as lighting. This means that certain colours that are reflected from the surface image can be seen as the same colour on the reflected image.

8.3 Three-dimensional

The drawing interface can be extended to work with three-dimensional art. On the surface, three-dimensional art can be created but on the mirror object, two-dimensional art is seen. A few works have been done on three-dimensional art such as Urban Architectural Ambience [15] and A New Kind of Three-Dimensional Anamorphosis [16]. To implement those features the whole drawing interface needs to be reworked to being able to work with 3D models.

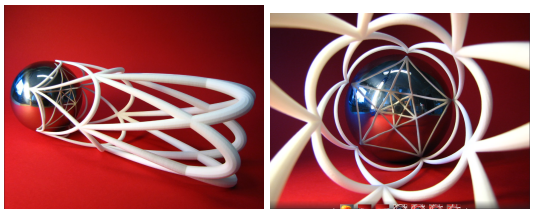

Figure 19: 3D anamorphosis with a spherical mirror and a distorted shape put on a cylinder. [17]

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