

Anamorphicons: an Extended Display Utilizing a Cylindrical Mirror Widget

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ABSTRACT¹

We propose an interactive system that implements the technique of Anamorphosis, with a flat-panel display and a cylindrical mirror. In this system, a distorted image is shown on a flat-panel display or a tabletop surface, and the original image will appear on the cylindrical mirror when a user puts it on the display. By detecting the position and rotation angle of the cylinder, the system provides interaction between the user and the image on the cylinder. We developed three applications using this device.

CCS CONCEPTS

• **Human-centered computing** → Interaction devices

KEYWORDS

Tangible; TUI; Anamorphosis; Tangible UI

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1 INTRODUCTION

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The mirror anamorphosis is an art technique of showing an image in a curved mirror. It is an optical phenomenon whereby when a curved mirror reflects a picture on a flat surface, the image of the picture reflected in the mirror appears distorted to an observer. In anamorphosis works, artists apply this phenomenon to show their painted works in a curved mirror, by painting a purposefully



Figure 1. Anamorphosis with a cylindrical mirror (left). An example of Anamorphicon: a tangible user interface widget using anamorphosis (right).

distorted picture on a flat canvas in such a way that the reflected image of the picture in the curved mirror is rectified and appears undistorted.

We have implemented an interactive cylindrical mirror anamorphosis using a flat-panel display and a cylindrical mirror placed on the display [2]. We named our cylindrical mirror widget “Anamorphicons” by combining anamorphosis and phicons (physical icons) [3]. By detecting the position and rotation of the Anamorphicon that is placed and manipulated by users, and by changing images on the flat-panel display, it can be applied to various interactive applications [2, 8].

2 Related Work

Since Hiroshi Ishii defined a Tangible User Interface (TUI) [3] as a means to a directly manipulate digital information with physical objects, there have been many efforts toward creating various TUI widgets. TUI widgets provide intuitive manipulation

because physical objects offer stronger affordances than graphical ones.

These widgets are made of materials such as wood and plastic and can be physically touched and operated by hand. Many of studies use "passive" approach to design TUI widgets, that is, widgets are made of wireless and battery-less mechanism to provide location, ID, and user-I/O functions. Such a mechanism has an advantage in terms of cost and maintenance. The typical approach to provide display function on the surface of TUI widgets is to utilize external projectors or flat-panel displays. One of the methods for doing it is trimming a part of the image according to the widget's shape and projecting it on the top of the surface using an overhead projector [4, 5, 14]. Another method is to use transparent widgets and an underlaid display [7, 10, 16]. Trimmed image according to the shape of the widget is displayed when a user put the widget on the display surface.

There are studies to propose more realistic passive display that gives illusions as if the widget is actually displaying image on the surface. Lumino [12] is a TUI widget made of optical fiber. It optically transfers a part of the image on an underlaid display to the top surface of the widget. Ficon [9] is also made of optical fiber and transfers underlaid images to its curved or slant surface. Although Ficon tries to realize three-dimensional (3D) surface display, a transferring image to the steep or standing surface is difficult due to optical fiber limitations. Using multiple projectors, almost all the surfaces of an object can be illuminated with 3D projection-mapping techniques. Tangible 3D Tabletops [13] uses the technique to realize passive display on TUI widget surfaces. However, it is generally difficult to provide 3D effects that jump out onto a table and achieve the illusion of the widget displaying something on its standing surface, with a simple and low-cost method.

3 ANAMORPHICON

As a new TUI widget, we propose a novel passive display widget named "Anamorphicons," which is a cylindrical mirror with small tips of conductive material. This widget is placed on a touch-sensitive flat-panel display, on which a distorted image is displayed around the widget. When a user sees the image through the cylindrical mirror, the original image can be seen over the cylindrical mirror widget.

3.1 Detecting Method

To detect the coordinates and rotation of the cylindrical mirror placed on a position-detectable flat-panel display, we attached three tips of conductive material at the bottom of the mirror cylinder. In this study, we used the capacitive touchscreen (9.7 inch iPad) as the position-detectable flat-panel display. The side of the cylindrical mirror consists of aluminum. The bottom of the cylindrical mirror consists of conductive PLA (Proto-Pasta, The volume resistance of conductive filament: $0.2\Omega/\text{cm}$) and non-conductive PLA (Proto-Pasta). The conductive tips and the aluminum cylinder are connected electrically to detect the user's manipulation. On the bottom side, when all three tips touched

the flat-panel display, the resulting touch patterns with A, B, and C

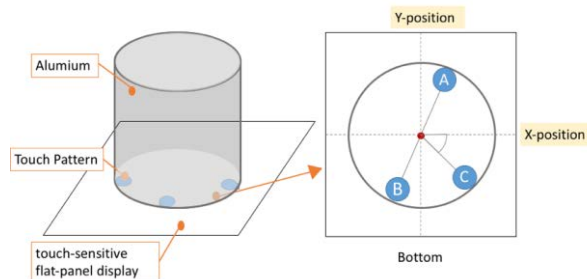


Figure 2. System detects an asymmetric polygon formed by the conductive tips on the bottom of the cylinder. It computes and follows the cylinder rotation of the angles.



Figure 3. Original image (left) is converted by polar transformation (center). By viewing the converted image through the cylindrical mirror, the user can see the original image flipped in the mirror (right). © J Collingridge Photography



Figure 4. System Usage. Rotating the object on the mirror.

are detected, as illustrated in Figure 2. The system can determine the rotation and the position information of the cylinder from the position of the touch patterns.

3.2 Display Method

In anamorphosis, the observer can see the original image in a cylindrical mirror. For that purpose, we have to convert the images. In this study, we use the polar transformation to convert the image for anamorphosis, as shown in Figure 3. In our implemented applications, images converted by polar transformation are displayed under the cylindrical mirror. When the user turns the Anamorphicon, images reflected on the cylindrical mirror surface are changed according to the rotation angle (Figure 4). This enables interactive tangible 360° view that displays all angles when a user rotates the widget. Additionally,

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the cylindrical mirror anamorphosis provides virtual image that pops up from the underlaid display. Thus, the Anamorphicon allows the user to semi-stereoscopically observe images reflected on the cylindrical mirror surface and still feeling that they are moving objects in their own hand.

4 APPLICATIONS

4.1 Electronic Commerce Application

Some electronic commerce web sites provide functions to manipulate product images by mouse operations and to check images from all directions. By using Anamorphicons for this operation, it will be possible to confirm the product from the whole surroundings in an easy-to-understand manner by an operation like a user holding the product by hand and rotating it. Figure 4 also shows a prototype of such an operation. It was implemented by using Objective-C. When the user selects one of the several items displayed on the flat-panel display and puts down an Anamorphicon on it, an image of the product viewed from the front is displayed on the cylindrical mirror. When the Anamorphicon is rotated and moved by the user's hand, the displayed product image is also rotated and moved. Thereby, it is possible to create the illusion of the product being rotated in the user's hand and to check the whole circumference of the product with the sense that it is directly in hand.

4.2 Video Conference System

Some teleconference systems, such as Hydra [1], use tangible widgets with a display and camera to materialize remote participants on a table. In these systems, the gaze directions of participants are correctly transmitted, and it can be controlled directly by hands of the person sitting at the table.

If Anamorphicons were used in such systems, they could be realized at low cost. Our application for doing it was implemented by using JavaScript, HTML5, and SkyWay² (WebRTC platform). We created an Anamorphicon with a USB connection camera at the top of it. A user who has the Anamorphicon in the remote conference (hereinafter referred to as *local user*), as shown in Figure 5, sets a large flat-panel display horizontally and operates this widget. The image of the user participating in the conference from a remote place (hereinafter referred to as *remote user*) is displayed on this Anamorphicon. Additionally, the image from the Anamorphicon's camera is sent to the remote user. When a local user takes a meeting with multiple remote users, multiple Anamorphicons are set and used. A local user can manipulate the positional relationship of remote users and their gaze direction by moving and turning the respective Anamorphicons. When the remote user uses a fixed camera for a normal video

conference, only images from the fixed one direction are displayed on the Anamorphicon. When all-around images of the remote user can be obtained, and each shooting from a specific angle is switched by rotating the Anamorphicon by the local user, a more realistic feeling of rotating the counterpart by hand can be provided. We create an arm device like Satellite Eyes [11] for shooting all-around images of the remote user, as shown in Figure 5 (left).

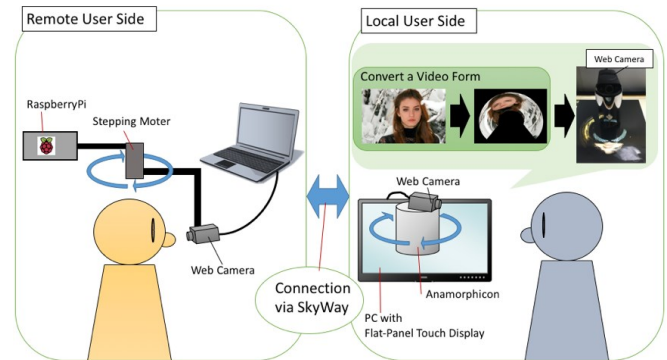


Figure 5. Overview of the video conference system.

This is a mechanism that obtains the all-around image of the remote user by rotating the arm with the camera attached at its tip. The arm is connected to a stepping motor above the remote user's head. When the local user rotates the Anamorphicon, the stepping motor rotates according to the cylinder rotation angle, and the image from the rotated position is displayed on the cylindrical mirror. Figure 5 shows the overview of the system. When we operate the system on the local network, the delay between the rotation operation and the camera movement stops was approximately 0.5-3.0 s.

4.3 Map-Based Navigation System

Map-Based Navigation System is a tangible map navigation system that allows users to decide the direction to walk through. In this application, it represents 360° sceneries surrounding an observation point. It was implemented by using JavaScript, and HTML5, and to obtain panoramic images, we used the Google Maps API³. When we adapt the panoramic scenery image to the cylindrical mirror and view from the outside of the cylinder, an appropriate mental model is required for the Anamorphicons. Our application employs a physical avatar, that is, the Anamorphicons represent a surrogate of a user. For ease in understanding the model, we attached a figure to the top of the Anamorphicons (Figure 6, right). This figure will make it clear that the reflected scenery corresponds to the viewpoint of the

² <https://nttcom.github.io/skyway/>

³ <https://developers.google.com/maps/>

doll position on the mirror. Figure 6 shows the application window displayed on a flat-panel display. The right-side window contains the map area while the left-side contains the distorted image of the sceneries. In the map area, a pictogram indicates the current position of a panoramic view. When a user drags a pictogram to any location, corresponding viewing images will appear on the left-side area. Then, as a user places the pictogram at any place, a user can get a view of the direction from the current position in the mirror. The application translates the angle of the direction of the view from the current position by utilizing the Anamorphicon's angle. Figure 7 shows snapshots of the application. An image of white arrows indicates paths for the next panoramic view existing in the direction. When a user puts a cylinder on the flat-panel display, a

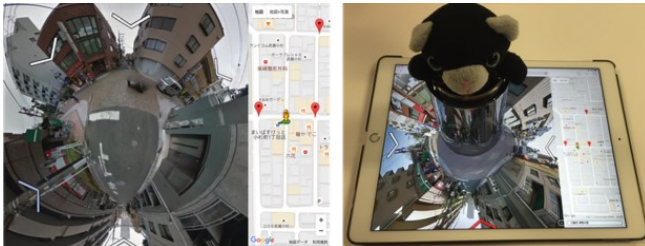


Figure 6. Screen shot of a distorted panoramic image and map view on an iPad (left). A user can decide the direction to walk through simply by rotating the Anamorphicons (right).

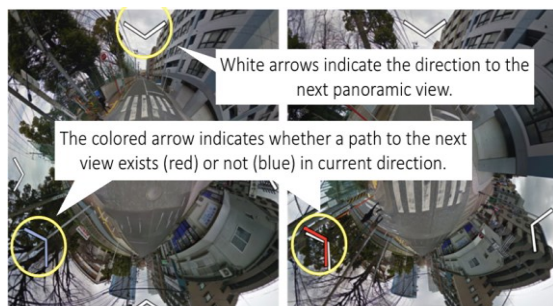


Figure 7. Snapshots of the map-view application.

blue arrow image is overlaid (Figure 7 left) on the panoramic image. It moves according to the cylinder rotation angle. When a user rotates the Anamorphicon to move the blue arrow to the white arrow direction, the blue arrow turns to red (Figure 7 right). Then a user can move to the next panoramic view by touching the flat-panel display.

5 DISCUSSION

We evaluated the usability of each application by System Usability Scale (SUS) [6] using 100 points scale (from 0 to 100, higher points imply better usability). Overall, 6 subjects (5 females) between 22 and 49 years old participated in the evaluation. They were lectured how to use each application and used freely in about 15 minutes. We calculated mean of SUS scores (M) of the participants. While Electronic Commerce

Application (M = 86.0, SD = 8.4, max = 92.5, min = 68.8) gets highest evaluation, Video Conference System (M = 65.8, SD = 15.9, max = 85.0, min = 40.0) and Map-Based Navigation System (M = 57.5, SD = 16.8, max = 80.0, min = 35.0) are evaluated lower. We consider that the concept of Electronic Commerce Application is easier to be understood and has simpler operations than the other two applications.

Besides the evaluation, we also demonstrated each application in several opportunities, and we received comments. Electronic Commerce Application was demonstrated at the ITS' 2011 [2]. At this time, there was an opinion that the item projected on an Anamorphicon seemed to be 3D. Although the virtual image that appears on the cylindrical mirror is not 3D, just pops up from the underlying display, it is possible that the interactivity with movement and rotation has enhanced the stereoscopic reality. Video Conference System was demonstrated for several people in our laboratory. When they tried the local side user, they commented that the remote user on the Anamorphicon seems to be facing the same direction as the top-mounted camera. At the remote side trials, they said that the moving camera-arm does not interrupt with their visual field. However, some remote users said that they felt the rotation of the camera was slow. This may be improved by accelerating the response of the arm device. In the Map-Based Navigation System, we demonstrated the system at the UIST' 2016 [8], and at that time, we got the feedback that the direction recognition is easy by using the system. This shows that the subjects understood well how to express the direction to walk through by the direction of the doll.

One of the negative opinions raised in general was that the deformed image displayed under the Anamorphicon widget occupied the display area on the flat-panel display. An angular-dependent optical film or display used in previous work [15, 17], will improve this issue. In addition, some people said that it is difficult to see the object displayed on the cylinder widget, because of limited view angle and small size of the virtual image. This issue is caused by the limited size of the distorted image on the underlying display. There is a trade-off between readability and efficient use of the display area. Further investigation on the shape of mirror other than a cylinder, may improve the issue.

6 CONCLUSION

In this paper, we implemented the Anamorphicon system as a passive TUI widget with low cost. Our system shows interactive images on a simple object without expensive parts such as batteries, LCD, or electric circuits. This system provides interaction between the user and the image on the cylinder by detecting the position and rotation of the cylindrical mirror widget. We showcased three different applications to highlight the flexibility of the approach. We believe that Anamorphicons has a wide range of potential available applications.

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