OmniEyeball: Spherical Display Embedded With Omnidirectional Camera Using Dynamic Spherical Mapping

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ABSTRACT
Recently, 360-degree panorama and spherical displays have received more and more attention due to their unique panoramic properties. Compared with existing works, we plan to utilize omnidirectional cameras in our spherical display system to enable omnidirectional panoramic image as input and output. In our work, we present a novel movable spherical display embedded with omnidirectional cameras. Our system can use embedded cameras to shoot 360-degree panoramic video and project the live stream from its cameras onto its spherical display in real time.

In addition, we implemented an approach to achieve the dynamic spherical projection mapping in order to project to moving spherical devices. We have also been creating applications utilizing system's features by using 360-degree panoramic image as input and output.

Author Keywords
Spherical display; omnidirectional camera; 360-degree panorama; projection mapping

INTRODUCTION
The sphere, as a typical geometric object, is used in lots of designs. In recent years, researchers started proposing spherical displays, such as Sphere [1] created by Benko et al., which is a system using spherical image as the output.

However, the existing works haven't tried to embed cameras inside their spherical devices. Camera is an important way to enable image input for interactive systems. Most of the current smart devices contains at least one camera in their bodies to create more features. For instance, Horita et al. [2] embedded a camera into a ball which made their device be able to provide point of view from the ball's position.

In addition, a special type of cameras is becoming increasingly popular. Within two years, more than ten kinds of omnidirectional cameras have been released, such as the Ricoh Theta S. They have been attracting many users depending on the amazing 360-degree panorama. Compared with original 2D images, the omni-panorama can provide 360*360 degrees graphic information in one picture.

Figure 1. Live streaming video captured by the embedded SP360 4K camera is projected on the spherical display.

Currently, there are many digital devices which are capable of both image input and output. For instance, people love to shoot and view pictures in their smartphone. However, there is still no similar device for 360-degree panoramic image. Due to the feature of spherical shape, spherical displays are the perfect matches for 360-degree panoramic image. Therefore, we decided to develop a new device which can both capture 360-degree panoramic image as well as display it.

In our work, we embedded panoramic cameras into the spherical display system. Our device can capture 360-degree panoramic images and also display spherical image. It's able to do panoramic live stream through wireless connection and the real-time panoramic image can be seen directly projected onto the spherical display itself with dynamic spherical projection mapping. We believe this new I/O device for omnidirectional image will bring users more interactive ways in daily life.

SYSTEM OVERVIEW
Currently, our spherical device consists of one rubber ball embedded with one PIXPRO SP360 4K digital camera on the pole. The SP360 camera is equipped with a fisheye lens which can cover 360-degree in horizontal direction has a 235 degrees field of view. Therefore, most of the surrounding environment of the spherical device can be covered by this SP360 camera with limited blind zone. Our proposed system streams live video to the PC, then integrates our dynamic spherical projection mapping technology and motion tracking

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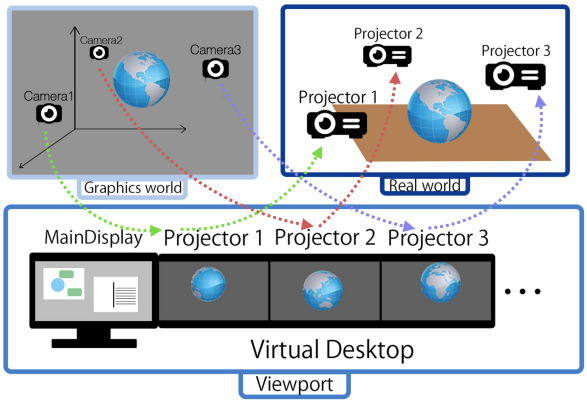

Figure 2. Diagram of spherical projection mapping.

system to project the live stream image onto its spherical display. Therefore, our device seems like a spherical mirror as shown in Figure 1 . The live stream we can receive from the SP360 4K camera has a 1280*720 resolution with 15fps when connected to the PC by WiFi. The format of the image is fisheye motionJPEG. In order to integrate the SP360 4K camera's live stream into our system, we transfer raw image into equirectangular format by using a fragment shader in the graphic system. This shader will do camera calibration to convert fisheye image to square image with high quality and low cost.

DYNAMIC SPHERICAL MAPPING

We proposed an approach to do 360-degree projection to moving balls in realtime. The positional relationship between the ball and projectors can be calculated by transforming projector positions in the real world to the camera coordinate system. We build a motion tracking system consisting of 6 motion tracking cameras to track the position of the moving ball. By combining three-dimensional ball positions from the motion tracking system, the system generates the projection images corresponding to each projector's position.

Figure 2 shows the diagram of spherical mapping. The different images in the virtual desktop are computed by the PC based on the position of the ball and projectors from the motion tracking system. Then, these images are projected by corresponding projectors from different directions to cover the whole area of the ball according to the ball's position and orientation. To put real-time projection into practice, this system overlays images without optimizing the overlapping parts.

EXAMPLE APPLICATIONS

We have been devoloping three applications utilizing the spherical and panoramic features of the system.

360-degree Panorama Viewer

In this application, we project the 360-degree panoramic image or video onto the spherical display. Compared with dragging the mouse to see the intended area, we believe that rotating a ball-shaped device is more intuitive.

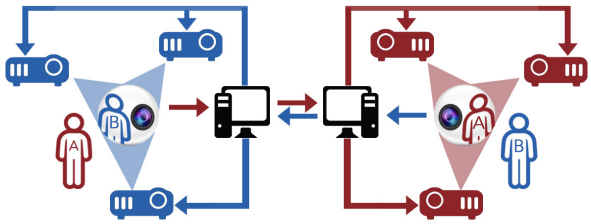

Figure 3. Remote Panoramic Video Chat.

Panoramic Selfie Camera

Users are allowed to take 360-degree panoramic selfies by using the spherical device in this application. Users can use the live streaming display to check what is captured.

Remote Panoramic Video Chat

Figure 3 shows a practical application we are still working on. This application allows users in different places to do video chat with 360-degree panoramic image by arranging two spherical devices in different places, such as conference rooms. Each spherical device will use its embedded cameras to capture surrounding environment, and the image data will be projected onto the other spherical device by the system.

We believe that our proposed system can improve remote conference meetings due to its panoramic and movable features. It will be efficient that people can just carry our spherical device to view every detail in the other place and simultaneously show important information in their surrounding environment.

DISCUSSION AND CONCLUSION

Until now, we have built a spherical system which provides panoramic image as input and spherical display as output. We also discovered how to do spherical mapping on a sphere more accurately. Finally, several applications have been created to embody the entertainment and practicality.

We are working on optimizing this system by embedding two PIXPRO SP360 4K digital cameras on the poles. In this case, the proposed system can capture the whole surrounding environment with only a tiny blind zone.

Moreover, we plan to enable gesture recognition as another input using image processing. We also consider to replace the display technology from projection to OLED, or the position of the spherical device might be tracked by sensors such as a GPS sensor in the future. In this case, we can build a mobile I/O device of 360-degree panorama in the future, just like the camera feature of the smartphone.

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