LiDARMAN: Reprogramming Reality with Egocentric Laser Depth Scanning

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Abstract

This paper introduces a method to reprogram reality by substituting visual perception. According to several studies in psychology, our construction of reality is only a subjective experience, and we have an ability to adapt the modified perception unconsciously. As we use a Light Detection And Ranging (LiDAR) sensor to provide altered vision, the system can provide a novel 3D reconstructed view from outside of the body. We explore factors that affect the behavior of the user with the out-of-body vision using a prototype of our proposed system LiDARMAN. Three different representations (1st person camera, 3rd person camera, plan view) are investigated to explore potential applications such like navigation, security, or remote collaboration.

Keywords: visual perception, sensory substitution, wearable

Concepts: •**Human-centered computing** → *Interaction devices;*

Figure 1: *The LiDARMAN prototype setup*

1 Introduction

Visual perception plays an important role in our daily life. With this perception, we can sense and interpret the surrounding environment by processing information that is contained in the visible light. Thus, our construction of reality shapes and alters our view of the physical world. Moreover, it also limits our cognitive ability and how we react to the environment because we heavily rely on our visual perception than other senses.

According to a German biologist Jakob von Uexküll, the reality is only a subjective experience, and it is a kind of illusion that we perceive. Different species, such as birds or insects, may recognize the world quite differently. He named this concept "Umwelt" (the German "surroundings") [Uexküll 1934]. This concept suggests that our behavior and perception are quite tightly connected for an understanding of the world.

In addition, as the experiment known as "Upside down glasses" [Stratton 1897] suggested, we have an ability to adapt to such a modified perception. A recent study [Mazzoni and Krakauer 2006] also supports this adaptation; the motor system can be reprogrammed by visual perception. It should be an interesting research direction to consider how we can alter our perception with technology. Such technology would be able to bring us an ability to perceive invisible information such as infrared lights, or electromagnetic field.

In this paper, we explore to use a Light Detection And Ranging (LiDAR) sensor, a 360° range scanner, as a perception changing technology. LiDAR sensors are becoming common as the introduction of self-driving cars and autonomous robots. It can measure the surrounding environment with depth information in real time, and its sensing range is about 100 meters, much longer than other depth sensors such as Kinect. If we substitute our vision with sensing information from LiDAR, we should be able to "see" the world in 360 degrees. It would be quite convenient for people who have to always aware of the surrounding environment. We can also look at ourselves from the outside, by using reconstructed range data.

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2 Related Work

There also exist previous attempts to provide an altered vision for users. FlyVIZ [Ardouin et al. 2012] is a 360° vision display. The system captures an equirectangular video stream with an omnidirectional camera on the user's head and directly displays the stream to HMD device. As a result user's field of view (FOV) is virtually enhanced and he can see surrounding environments at once. SpiderVision [Fan et al. 2014] also provides an enhanced field of view but with front and back cameras mounted on HMD. The back-side view is overlaid on front-side view with pixel blending. Although those systems enhance the field of view, a viewpoint is not altered. This is because depth map of the surrounding environment is unknown, so technically hard to view from outside of the users' body. Our proposed system enables the out-of-body experience, although the image resolution is still limited compared to ordinal image sensors. We assume this free viewpoint functionality is the key to get a better understanding of the perceptive world.

One good example of this out-of-body experience can be seen in the concept of JackIn [Kasahara and Rekimoto 2014]. The system enables to share the other person's surrounding view but in stabilized form, so that the user can naturally look around the environment independent to head motion of the other person.

3 LiDARMAN

We propose a combination of an omnidirectional range scanner and a 3D head mounted display (HMD) for substituting our visual per-

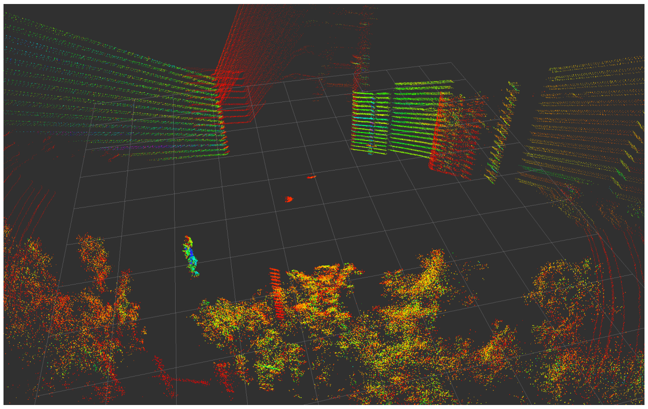

Figure 2: *An example of point clouds in 3rd person view*

ception with surrounding depth information.

The depth perception is important to sense the relative distance to environmental obstacles and is essential for a fundamental navigation task. Through our two eyes, we perceive a depth using two kinds of cues: monocular cues (e.g. perspective, occlusion, etc.) and binocular cues (e.g. stereopsis, convergence, etc.) However, the field of view provided by this optical organ has been limited (binocular vision only covers around 114 degrees in horizontal). We use a range sensor to provide omnidirectional depth information and feed into 3D visual representations in several ways.

The LiDAR sensor is a stack of mechanically rotating laser line scanners and is often used in robotics especially in the self-driving car applications nowadays. Although it is not a cheap sensor at this moment, we expect the price will go down to fit consumer products due to its potential needs from automotive industries. For example, several companies are announcing a plan of new product line based on an optical phased array with much lower price.

3.1 Implementation

The system is composed of a LiDAR sensor and a VR Head Mounted Display (Oculus Rift DK2). The sensor is mounted on top of the user's head to avoid possible occlusion caused by self-body. We integrated the system into a helmet type mount shown in Fig. 1. The sensor is connected to a laptop PC via Ethernet. All the ranging data are sent to the PC, and converted into depth point clouds around the user (Fig. 2).

3.2 Sensors

We use LiDAR sensor (Velodyne VLP-16) for vision substitution because of its depth sensing capabilities and wide field of view coverage. Although the resolution of the sensing result from its 16 laser line scan units is rather limited in low fidelity, the characteristics of 360-degree coverage and higher frame rate are much more important for the purpose of our proposed method.

To track an ego-motion of the user's head, we use location information calculated with SLAM algorithm using the range data along with an inertial measurement unit (IMU) integrated into the HMD.

3.3 Simultaneous Localization And Mapping (SLAM)

As noted before, LiDAR sensor is becoming a key component for robotics. We can use similar techniques to reconstruct and localize a moving subject. The technology is called simultaneous localization and mapping (SLAM) based on iterative closest point algorithm. In our implementation, we use ROS software environment and point cloud library to process 360° data every 100 ms.

3.4 Visual Representation

To investigate a better representation of reality, we explore several possibilities for the method of visual representation as an altered visual perception. According to the example in commercial game products [Haigh-Hutchinson 2009], effective position of a scene camera (view point) depends on the situation of the subject (e.g. moving state, direction, speed etc.) As an initial study, we tried these three static strategies for viewpoint settings; 1st person, 3rd person, and top plan view.

4 Conclusion and Future Work

In this paper, we proposed a system that enables us to perceive omnidirectional depth information by using real-time mappings of egocentric laser depth scanning. With this altered vision and the result of the 3D reconstruction, a viewpoint of the virtual camera can be moved outside of the body to get better perspectives of the surrounding environment. We investigated possible types of visual representation with preliminary user testing and got several implications for further design exploration towards our proposed concept of reprogramming reality.

As explained in the paper, visuomotor adaptation is a known physiological phenomenon, although less discussion has been done in HCI communities. We expect further work of this research opens up the door to utilize this interesting cognitive ability for potential applications in the near future.

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