Wide Angular Range Dynamic Projection Mapping Method Applied to the Projection on a Flying Drone.

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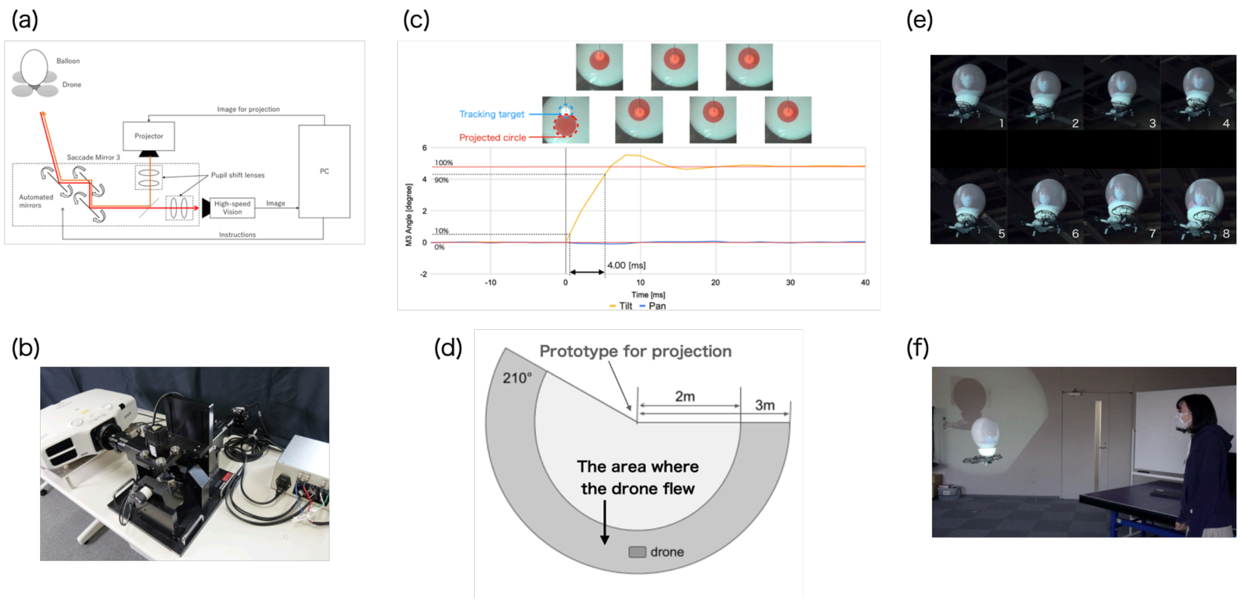

Figure 1: (a) System connection. (b) Photo of the prototype system. (c) Step response in tilt direction with the frontward initial gaze direction. (d) Schematic figure of the area where projection was possible. (e) Sequence of photographs of projected image on a flying drone in the projection experiment over 180 degrees in pan angle. (f) Communicating with remote locations.

ABSTRACT

In this study, we proposed a method to realize dynamic projection mapping on a target moving at high speed in a wide angular range around the projection equipment using a high-speed gaze control system, and actually implemented and evaluated it. We also combined the proposed system with a teleconferencing system, and conducted an experiment in which a drone was used as an avatar robot for communication with remote locations.

KEYWORDS

Dynamic projection mapping, Drone, High-speed gaze controller, Avatar robot

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1 INTRODUCTION

In recent years, dynamic projection mapping has been attracting attention. In conventional projection methods, the range of angles that can be projected is limited when images are projected by a fixed projector. In this study, we proposed a method to control the projection position in a wide range of angles at high speed by combining a high-speed optical gaze control system, a projector, and a high-speed vision system, and evaluated the performance of a prototype system. In addition, as a promising application of the proposed system, we demonstrated the possibility of using drones as avatar robots by using the developed prototype in combination with a teleconference system.

2 PROPOSED METHOD

In this paper, we propose a method that can control the projection direction as fast as milliseconds and over a wide range of angles of 210 degrees. This fast and wide projection direction control was achieved by a special high-speed gaze control system, Saccade Mirror 3[Iida and Oku 2016], which can control the gaze over a range of 180 degrees in the pan direction.

Saccade Mirror 3 has a structure in which three rotating mirrors and a pupil shift lenses are placed in front of the camera. The three rotating mirrors are combined to control the gaze direction.

The system connection diagram of the proposed system is shown in Figure 1(a), and the photograph of the prototype system is shown in Figure 1(b).

In projection mapping with high-speed gaze control system, the direction of gaze is always overlapped on the target to enable the projection to match the target. In order to achieve this, a high-speed vision system was installed in Saccade Mirror 3. The position of the target is recognized from the image captured by the high-speed vision, and the rotating mirror is controlled so that the gaze overlaps with the target.

Due to the effect of the arrangement of the three mirrors, the image presented to the projection target appears tilted to the viewer of the projection mapping. To solve this problem, we calculate how much the basis vectors of the projection coordinates are tilted from the axes of the real world, and then rotate the image in the opposite direction by the amount of the tilted angle, so that the observer can see the correct image.

In the following experiment, a projector and a high-speed vision system with 500 fpswere connected to the prototype of saccade mirror 3. To facilitate the detection of the target, retro-reflective material was used as the tracking target.

In the following, we also use two angles, pan and tilt, to describe the orientation of the object as seen from the system.

2.1 Step response measurement

To evaluate the gaze control performance of the proposed system, we measured the step response of gaze direction.

First, with tracking stopped, the tracking target was shifted in a certain direction from the center of the field of view. We then started tracking and measured the pan and tilt angle profiles until the object was in the center of the field of view.

Figure 1(c) shows the results of the step response in the tilt direction when the initial gaze direction was (pan, tilt) = (0, 24) degrees. The image sequence of the tracking target and projected image is shown in the upper part of the figure. The rise times of 4.1 to 6.4 ms were measured for three kinds of initial gaze directions. The results showed that the projection direction reached the target direction in about 8 ms in all cases.

2.2 Projection experiment over 180 degrees in pan angle

Next, we conducted an experiment to verify that the proposed system was able to project while moving the object around the projection system for more than 180 degrees.

A drone (Mavic Mini, DJI) with a screen attached was used as the projection target. A white balloon fixed on a hemispherical styrofoam covered with retroreflective materials was adopted as a screen. The drone was always flown at a distance of about 2-3 [m] from the saccade mirror 3. After visually checking whether the projection of the image continued toward the tracking target, the transition of the projection direction and the projection range were obtained from the log of the mirror angle of the saccade mirror 3.

The minimum angle of projection direction in the horizontal direction was -100.92 degree, and the maximum was 110.47 degree. Thus, this projection system was able to project an image over about 210 degrees in the pan direction.

Dark gray areas in Figure 1(d) shows the range where the image could be projected to the drone, as determined from the results.

We also confirmed that the prototype system could continue to project images toward the target during the tracking, as shown in Figure 1(e).

2.3 Drone as a avatar robot

Next, we demonstrated on-line communication with remote locations using dynamic projection mapping on flying drone.

We used Zoom for on-line communication with remote areas. The image of the remote conversation partner was projected onto the balloon, and the image from the camera mounted on the drone was sent to the remote partner.

Using the above setup, it was confirmed that a remote person and a local person can talk to each other while viewing the video. As shown Figure 1(e) and (f) of the figure, the drone is moving through space with the Zoom screen sent by the remote person projected onto the balloon.

This result shows that the proposed method can be used to project images onto a drone and utilize it as an avatar robot. Although current drones that use propellers are not suitable for use as avatar robots due to their noisy sound, balloon type drones filled with lighter- than-air gas have been developed recently[Yamada et al. 2019]. Since these drones emit almost no noise, we believe that these balloon type drones can be used as avatar robots in the future.

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