Three-dimensional behavior measurements of small aquatic lives using a single camera

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1. Introduction

The automatic inference of depth information has been one of the primary aims of computer vision system. Stereo vision that calculates the depth by analyzing two or three frames viewed from different angles is used in many cases. The results essentially depend on how accurately matching pairs can be found between these frames. The problem related to the stereo vision is that finding matching pairs between frames causes difficult computer processing since there are, in general, several possibilities for the choice of the matching point.

In order to cope with the matching problem and improve the measurement accuracy, we developed CDS (Circular Dynamic Stereoscopy) which uses a single CCD camera [1-4]. By introducing coupled mirrors on the camera lens, measuring points which appear on the image plane is displaced according to the depth. Upon rotating the coupled mirrors, these measuring points are shifted and appeared to be circular streaks on an image plane. The size of the circular streak directly relates to the depth of the measuring point. The depth can be measured easily by processing the circular image, where the cumbersome task to find matching pairs is not necessary. The three dimensional information of the measuring points can be found by processing the streaks.

Another feature of our system is the registration of motion information of measuring points. In the case that the measuring point is moving on parallel direction with the retinal plane, the shape of the streak appeared on the retinal plane is changed from circle to spiral. Since the frequency of coupled mirrors rotation is constant, the pitch of the spiral streak is directly proportional to the velocity of measuring point. In the case that the measuring point is moving on vertical direction with the retinal plane, the size of spiral streak is varied according to the depth. Therefore, the spiral streak has all 3-D information such as 3-D position and 3-D motion of measuring point and this information can be estimated using image processing technique.

On this workshop, three-dimensional measurement technique of moving small aqua lives in a tank using the proposed measurement system is introduced. The experimental result shows the feasibility of our system.

2. Measurement system

In order to realize the CDS in compact setup, we developed the following system that added a circular shift to the image. Fig. 1 shows schematic diagram of CDS system and Fig.2 shows the optical device on CDS system. By introducing a beam-splitter and a coupled mirror on the CCD camera lens, one of the images of the measuring point is directly recorded by the CCD through the beam-splitter and the other image is displaced by the combination between the coupled mirror and beam-splitter.

The magnitude of the displacement is related to the distance between the beam-splitter and the coupled mirror. The displacement that appears on the CCD is related to the distance between the CCD camera and the measuring point [5]. That is, the displacement r in the image is inversely proportional to the distance D between the measuring point and the camera as:

$$D = \frac{f \cdot d}{r} \tag{1}$$

where *f* is the focal length of the camera and *d* is the magnitude of the image shifting by the beam-splitter and coupled mirror.

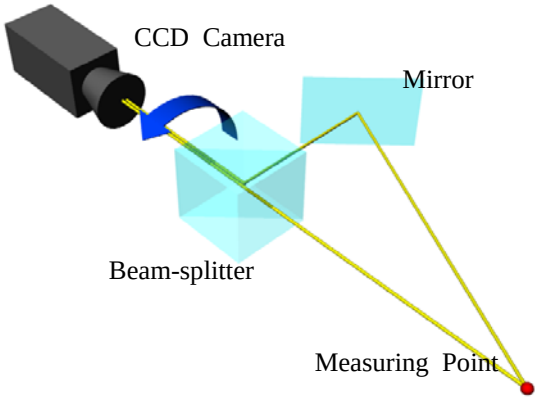
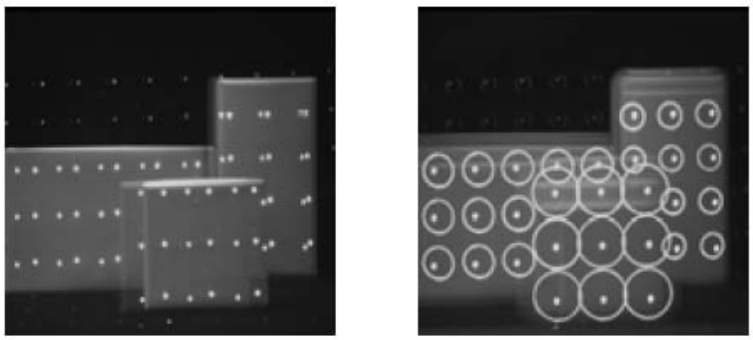


Fig.1 Schematic diagram of CDS system

Fig.2 Optical device of CDS system

When the beam-splitter and the coupled mirror are rotated physically at high speed during the exposure of the CCD camera, the annular streak and its center for each measuring point appear on an image since the rotational shift is added to the image. Fig. 3.a shows the multi laser spots projected on the surface of object and Fig.3.b shows the image with circular shift produced by our system. Since the size of the streak is inversely proportional to the distance of the measuring point from the camera, each annular streak contains three-dimensional information of the measuring point. The position and the size of the annular streak in the image are related to the three-dimensional location of the measuring point.

If the measuring point is not stable, a spiral streak appears since the movement of the measuring point is added to the rotational shift. In this case, 3-Dimensional position and the velocity of the measuring point can be obtained simultaneously by analyzing the variation in the radius of spiral streak. Fig.4 shows the example of spiral streak of moving tracer particle in the water flow.



a. Image without circular shift. b. Image with circular shift.

Fig.3 Image obtained by CDS

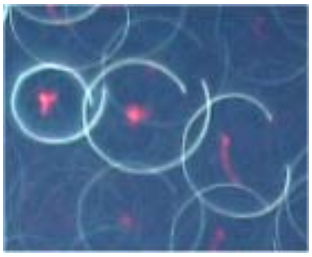


Fig.4 Image of moving particles

3. Measurement of the behaviour of Artemia

Measurement of small creatures in the water is the primary aim of the CDS system. Figure 5 shows the figure of Artemia that size is about 1 mm. By measuring the positions of the artemia continuously, the three-dimensional behaviour of artemia can be measured. Figure 6 shows the experimental setup used to demonstrate the measurement ability of the system. The distance between the centre of the tank and the measurement system is approximately 300 mm and the light is projected from its side. The artemia which size is around 1.0mm are put into the water tank. The acquired images at the sampling rate of 30Hz are shown in figure 7. This picture shows the five times overlapped image. The analyzed result of the behaviour of artemia is shown in figure 8. As shown in this figure, the behaviour of artemia is properly measured.

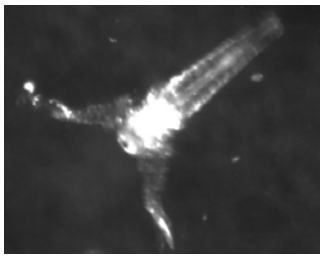


Fig.5 Artemia

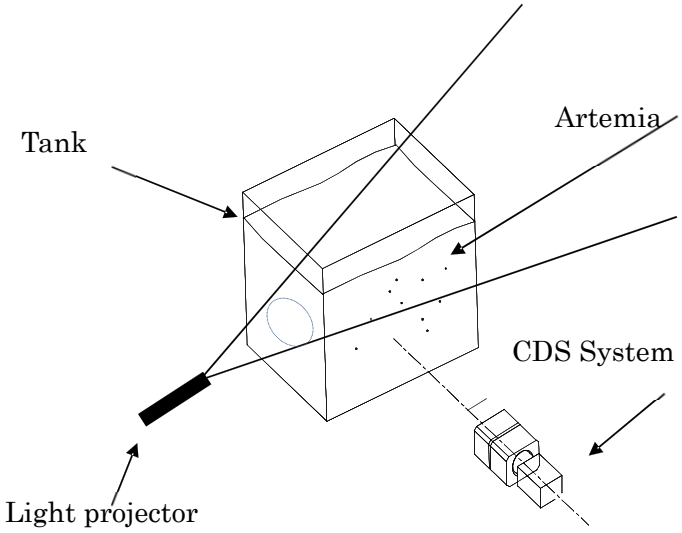


Fig.6 System setup for experiment

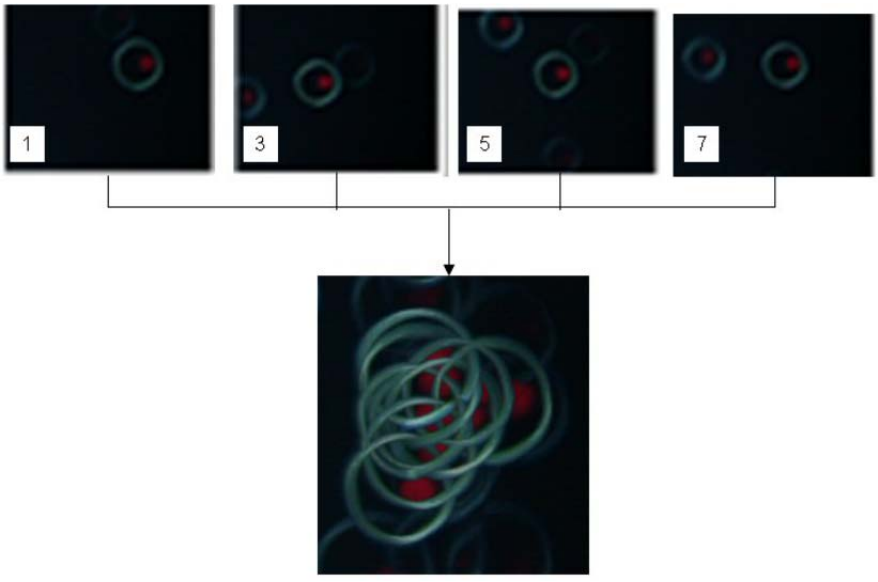


Figure 7: Recorded images of Artemia

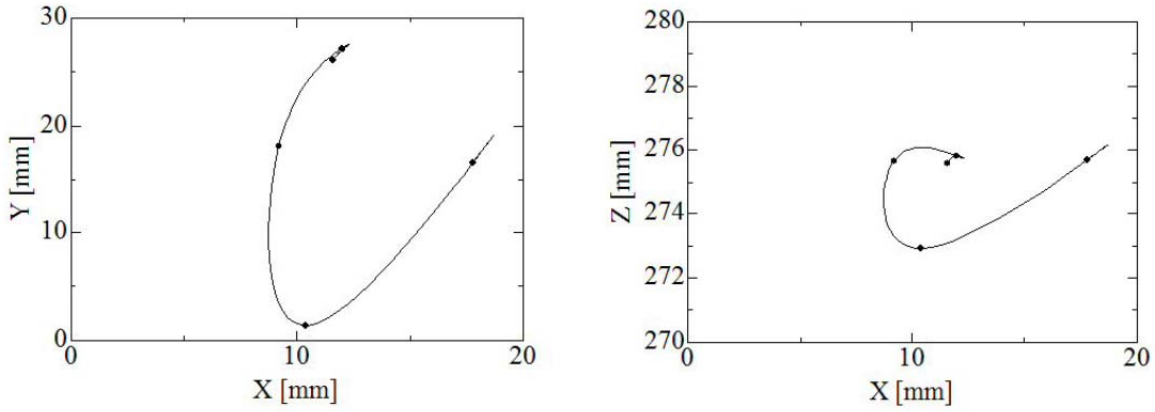


Fig.8: Analyzed result of the movement of Artemia

4. Conclusion

We have introduced a new approach for obtaining depth/distance information. A single camera and an image rotation apparatus record three-dimensional information on a single image. Each circular streaks recorded on the image plane relate directly to the 3D positional information of the individual measurement points. On the workshop, an image processing technique to obtain the three-dimensional information of moving points is introduced. The three-dimensional information of the measurement points is obtained using an image processing technique.

The proposed system is compact and the setup is simple because a single camera is used. Therefore, the system is expected to provide a useful tool for the investigation of the behavior of the small creatures. Experimental results demonstrate the feasibility of the proposed system

5. References

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