DETECTION OF BIRDS FLYING IN THE AERODROME BY IMAGE ANALYSIS

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ABSTRACT

Image processing method to measure the three-dimensional position and velocity of flying objects in hundreds meter scale has been developed. This technology can be applied for monitoring of bird density in aerodrome as a counterpart of radar which senses only high-speed flying birds at far distance more than 2km. We have examined our bird detection that bases on differential imaging which detects only temporally varying object in brightness between two consecutive images. The applicability of the method is evaluated in an aerodrome after the detection performance in different weather and hours were comprehensively tested in a large university farm. In addition, use of dome-shaped mirror mounted on the camera is also examined in order to capture flying birds in all 360 degree above the ground. After a series of performance tests, we conclude that the present bird detector works within the circular area of 1500 m in radius from the camera and is feasible for accumulating seasonal bird density data

Key Words: Bird detector, Image sensing, Natural background, Weather dependence

INTRODUCTION

Number of bird strike accidents for aircrafts reaches at around 6,000 in USA as average annual report, and Japanese airline companies also experience more than 1,000 a year. Among them, large birds such as raptorial occupy 100 and damages bodies and engines to result in severe accidents. Fall of aircraft into Hudson River on January 15, 2009 as shown in Fig. 1(a) triggered the planning of substantial response for bird strike avoidance all over the world. Engine loss is still reported often as shown in Fig. 1(b) and (c). In order to avoid the accidents, bird-patrol team in each airport is employed for scaring birds away from aerodrome [1]. If birds were detected automatically at real time, the work efficiency of the bird patrollers would be significantly improved. Such a detection system would also contribute to integrate statistic database in terms of hour, weather, and seasonal characteristics of birds surrounding aerodrome, which can be used to alert aircrafts with bird strike danger. Necessity of such a development of bird density measurement is also proposed in international meeting of provision for aerodrome bird strikes. Radar can detect large birds, however, it fails to sense them when flying in the space nearer than 1 km from the radar source or just flying near the ground. Unfortunately 80 % of bird strike accident of commercial aircraft happens to the case below 150 m high from runways. This is reasoned by the fact that birds often live in reservoir and seashore areas around aerodrome.

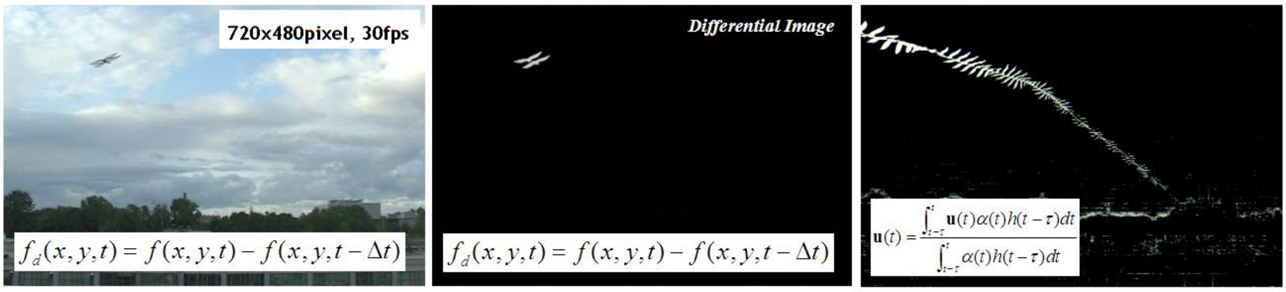
The authors have recently developed a flying-object monitoring system, which bases on stereoscopic particle tracking velocimetry (3-D PTV). A demonstration was made when it was applied for fireworks [2]. The system is coupled with a moving-object detector that is available for natural background light. This will enable us to monitor birds flying in the distance nearer than 1 km from the instrument as a counterpart technique of radars. Moreover the system has a potential to distinguish variety of birds thanks to optical sensing. The present paper describes these basic principles of the bird detection and the result of performance tests done in our university farm and in New-Chitose airport, Hokkaido, Japan.

(a) Hudson river in USA **(b) Heathrow airport in UK** **(c) New-Chitose airport in Japan**

Figure 1. Bird-strike accidents resulting severe damages on craft body and jet engines

BIRD DETECTION PRINCIPLES

When detection of moving object is required from natural background image, temporal differentiation of image brightness distribution between two consecutive images is simply applicable. Fig. 2 shows a sample of image detection for a crow flying in the sky at our university campus [3]. The original image involves clouds, trees, and buildings in the single frame as shown in (a). Taking the differentiation yields to erase all the stationary objects and to detect the crow as in (b). Sequential computation of the differentiation captures trajectory of the bird as in (c). The present principle is quite simple and thus feasible to realizing the on-time detection of birds. Sometimes the detection may fail owing to uncontrolled optical condition in nature, however, the bird trajectory can be reconstructed when a least data of bird position is obtained during the fly with a filtering function which is shown in the figure.



(a) Original image (b) Differential image (c) Integrated differential image

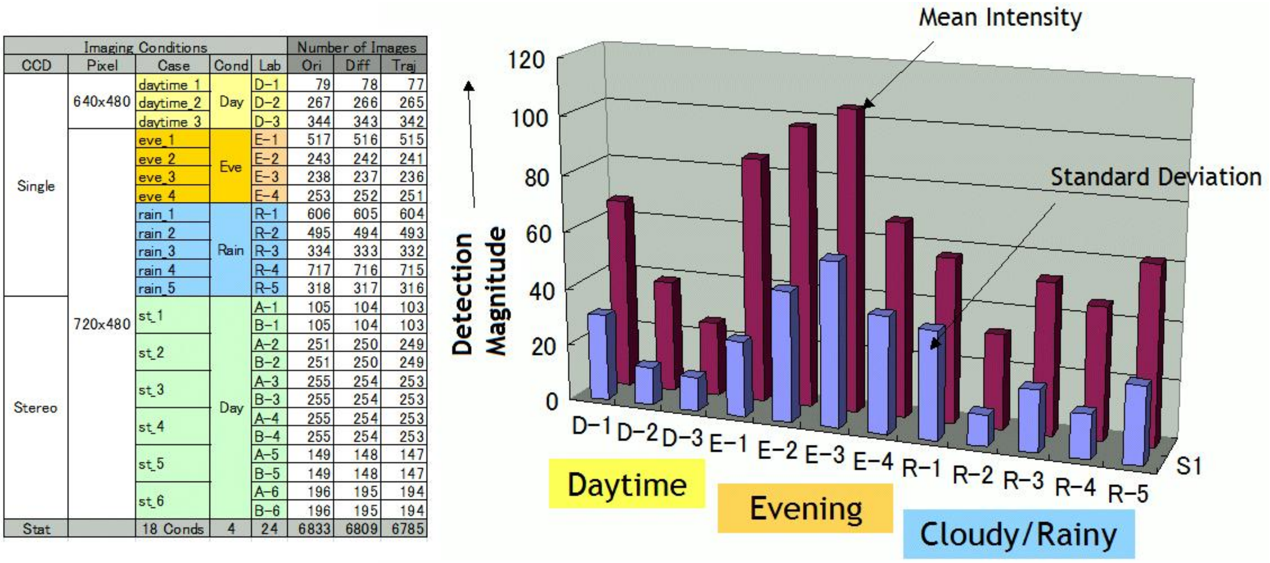
Figure 2. Flying bird detected by temporal differentiation scheme at Hokkaido university farm test

BASIC PERFORMANCE TEST

The bird detection performance of temporal differentiation is examined for 20 conditions in different hours and weathers at Hokkaido university farm. Fig. 3(a) shows instantaneous images of the background image; daytime in sunny weather, evening time in sunny, rainy condition in daytime, following-the-Sun image in sunset time, and against-the-Sun image in sunset time. Fig. 3(b) shows enlargement of bird image in original image (o), and in temporal differentiation image (c). As the color of the image shows, the temporal differentiation of image brightness distribution between two consecutive images derives higher chromatic information. Yellow-to-blue gradation of the hue indicates the direction of bird’s motion from left to right. Therefore, the temporal differentiation of bird image informs us not only the size and the shape of the bird, but also the direction of the motion.

(a) Natural background images for performance test **(b) Enlargement of bird image**

Figure 3. Series of hours and weather conditions for testing bird detection performance

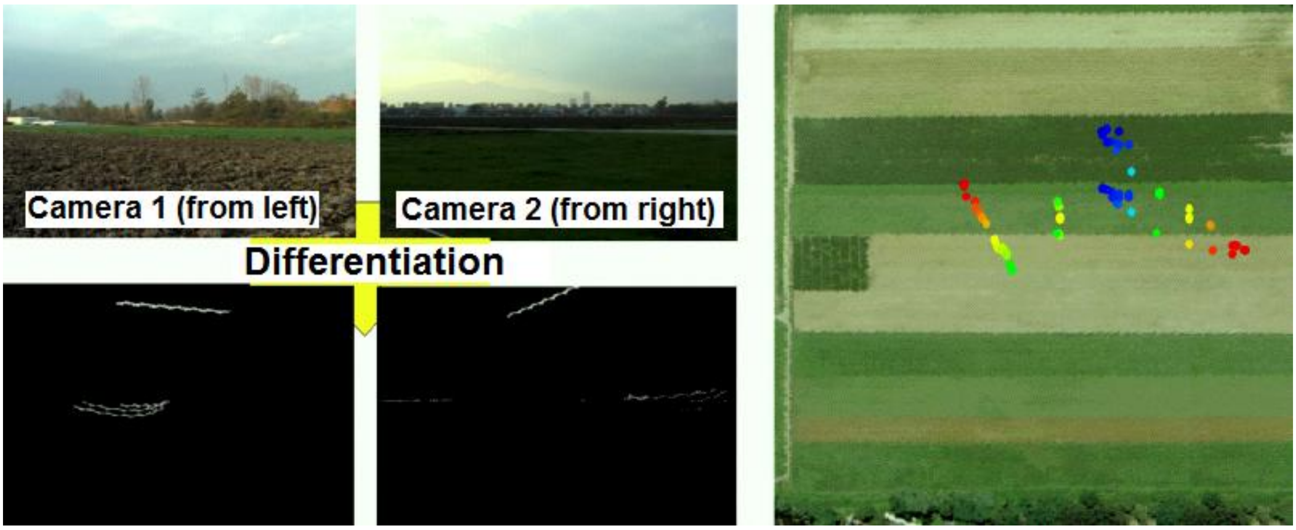


Imaging Conditions					Number of Images		
CCD	Pixel	Case	Cond	Lab	Ori	Diff	Traj
Single	640x480	daytime_1	Day	D-1	79	78	77
		daytime_2		D-2	267	266	265
		daytime_3		D-3	344	343	342
	720x480	eve_1	Eve	E-1	517	516	515
		eve_2		E-2	243	242	241
		eve_3		E-3	238	237	236
		eve_4		E-4	253	252	251
		rain_1	Rain	R-1	606	605	604
		rain_2		R-2	495	494	493
		rain_3		R-3	334	333	332
		rain_4		R-4	717	716	715
		rain_5		R-5	318	317	316
Stereo		st_1	Day	A-1	105	104	103
				B-1	105	104	103
		st_2		A-2	251	250	249
				B-2	251	250	249
		st_3		A-3	255	254	253
				B-3	255	254	253
		st_4		A-4	255	254	253
				B-4	255	254	253
		st_5		A-5	149	148	147
				B-5	149	148	147
		st_6		A-6	196	195	194
				B-6	196	195	194
Stat		18 Conds	4	24	6833	6809	6785

(a) Number of images tested **(b) Performance of bird detection**

Figure 4. Performance of bird detection for different hours and weathers

Fig. 4 shows the statistic results of the performance test. Figure (a) shows the table of the examination conditions. The sampling number for statistic evaluation ranges from 79 to 606 so that sufficiently reliable average is obtained. Figure (b) represents two statistic values of bird detection performance classified by three kinds of natural background conditions; daytime, evening, and cloudy/rainy. Mean detection intensity shown by purple bars becomes high for evening hours, and decreases at daytime. This is because the sunlight project birds stronger at evening time more than in daytime to make high contrast in the differential image. Standard deviation shown by blue bars indicates the fluctuation of bird detection, i.e. instability of sensing. While the deviation increases at evening time due to fluctuating contrast of background, it calms down for cloudy and rainy conditions because the background becomes uniform. This means that cloudy and rainy conditions are rather suitable than clear sky when flying birds are detected with the present method.



(a) Stereoscopic imaging using two cameras **(b) 3-D trajectories of detected birds**

Figure 5. Stereoscopic bird detection for measuring 3-D trajectories of birds flying above ground

Fig. 5 shows an application of the present method to three-dimensional measurement. A stereoscopic monitoring system is constructed using two cameras which are located at 100 m distance to each other in the farm. Synchronizing the two cameras, the same birds flying above the farm are recorded by the two cameras in nearly orthogonal direction as shown in (a). A simple algebraic computation of the bird coordinates in each image reconstructs three-dimensional coordinate of the birds as a function of time as shown in (b). Plots in the figure indicate the horizontal coordinate of four birds, and their colors means the progress of time from red to blue.

APPLICATION TO AERODROME

The present system is applied for bird detection in an actual aerodrome at New-Chitose airport, Hokkaido, Japan. As Fig. 6 shows, we set cameras at three different locations around the runway. A man in the middle picture B is the first author of this paper. At the location A, a camera with fish-eye lens is used to capture birds widely from the ground. The location B is on the roof of central terminal building, from which birds crossing the runways are monitored with a high-resolution camera. The location C is also on the roof of another building at the middle of the runway. At this site, we examine the availability of a dome-mirror camera that captures the entire image surrounding it.

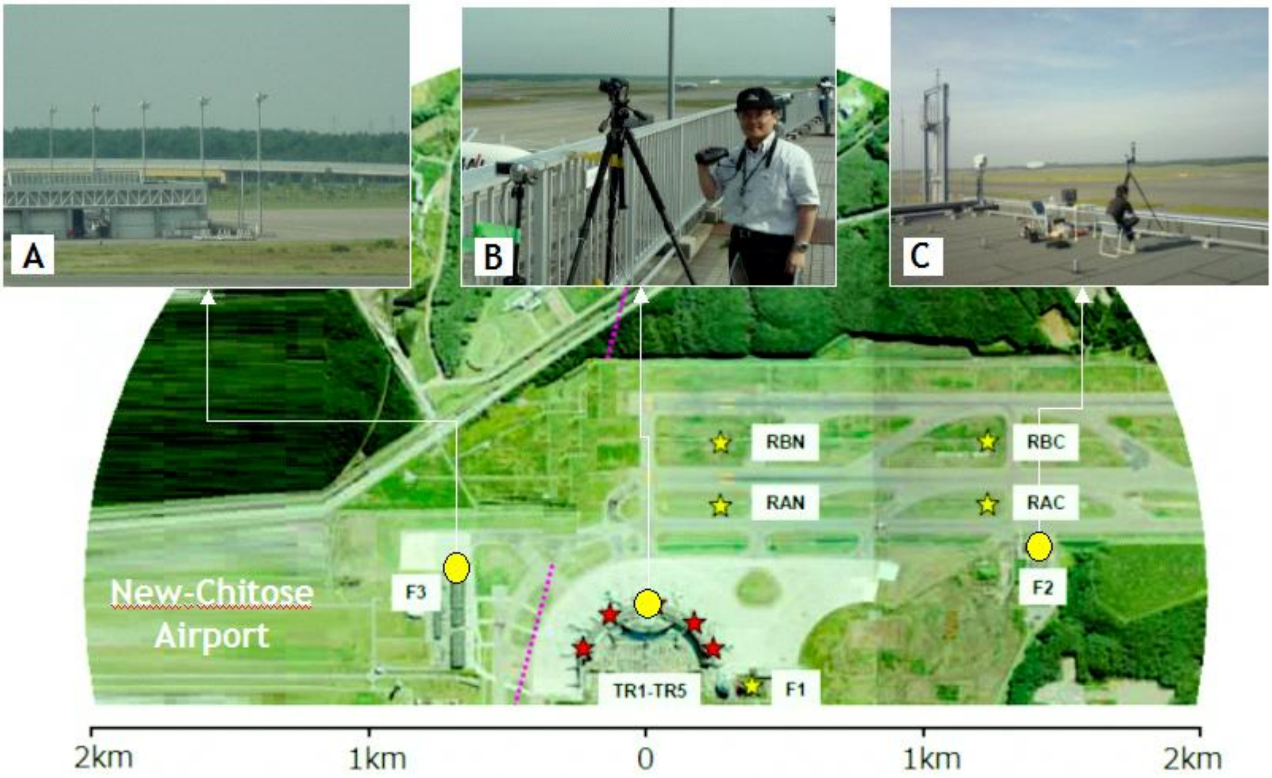


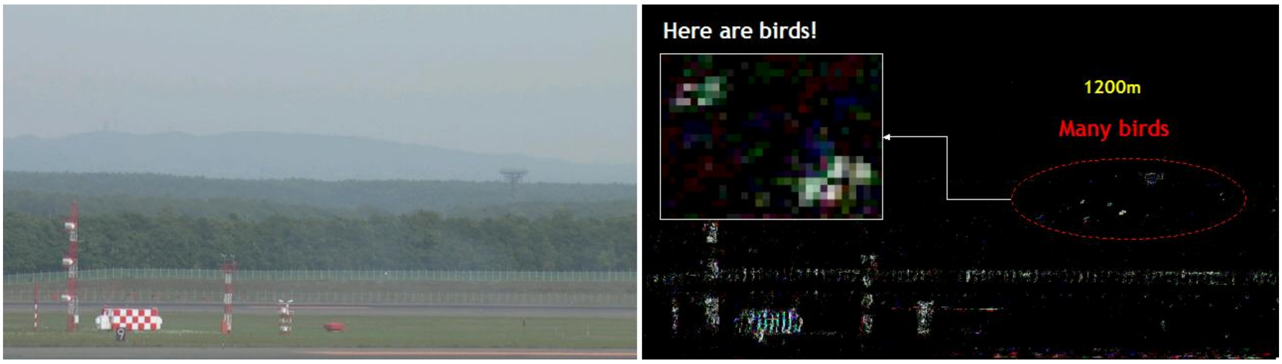
Figure 6. Three locations of different cameras at New-Chitose airport, Hokkaido, Japan

4.1 High-Resolution Imaging

Fig. 7 shows a case of successful bird detection at the location B. The image size is 1920 x 1080 pixel on 8 x 3 bit color mode, which is recorded at a frame rate of 30 fps. In the original image (a), finding a bird in the image is almost impossible. The differential image (b) indicates a local high brightness above the runway due to presence of flying bird. The bird at this moment flies at 300 m from the camera, and it consists of around 20 pixels as shown by enlargement.

(a) Original full color image **(b) Bird detected in differentiation image**

Figure 7. Bird detection from high-resolution camera at location B (Case 1: bird flying above runway)



(a) Original full color image **(b) Bird detected in differentiation image**

Figure 8. Bird detection from high-resolution camera at location B (Case 2: birds flying on forest)

(a) Original full color image **(b) Bird detected in differentiation image**

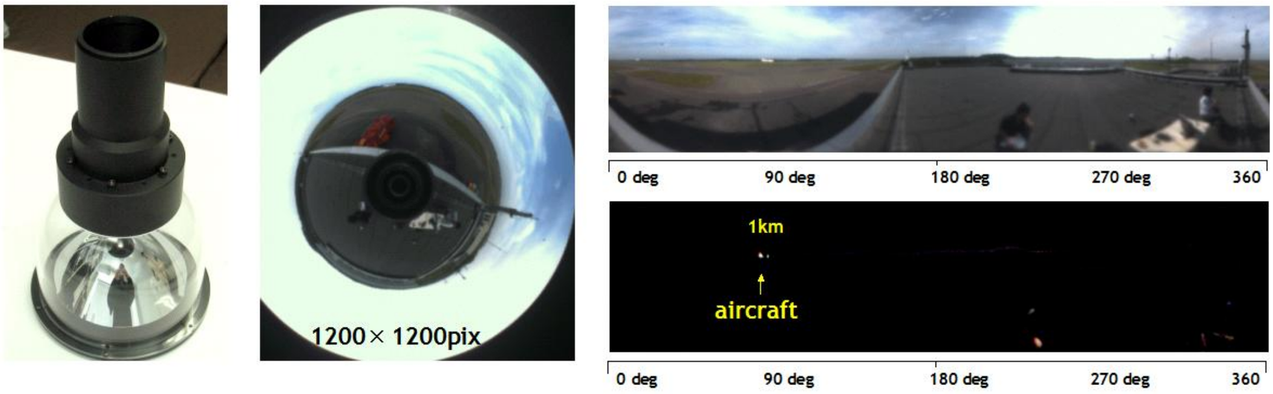
Figure 9. Bird detection from high-resolution camera at location B
(Case 3: many crows flying above waste treatment center beside the aerodrome)

Fig. 8 shows another examples of successful detection at location B. While the original image does not indicate clearly the birds, the differential image reveals a number of birds flying above a forest beside the runway. In this case the birds fly at around 1,200 m from the camera. On the other hand, a checker box on the ground remains in the differential image, which must not move actually. This is one of disadvantage of the temporal differentiation method, which comes up when complex image pattern is included in the view. Poles consists of thin bars and net fences are also left in the differential image. However these are usually fixed in real space, and the projected coordinate on the image plane is given. Hence flying birds and fixed object with complex image pattern are basically distinguishable.

Fig. 9 shows the case of hundreds of crows flying around a waste treatment center which exists beyond the forest. They are flying at 1,500 m from the camera, and single bird consists of around 10 pixels on the image plane.

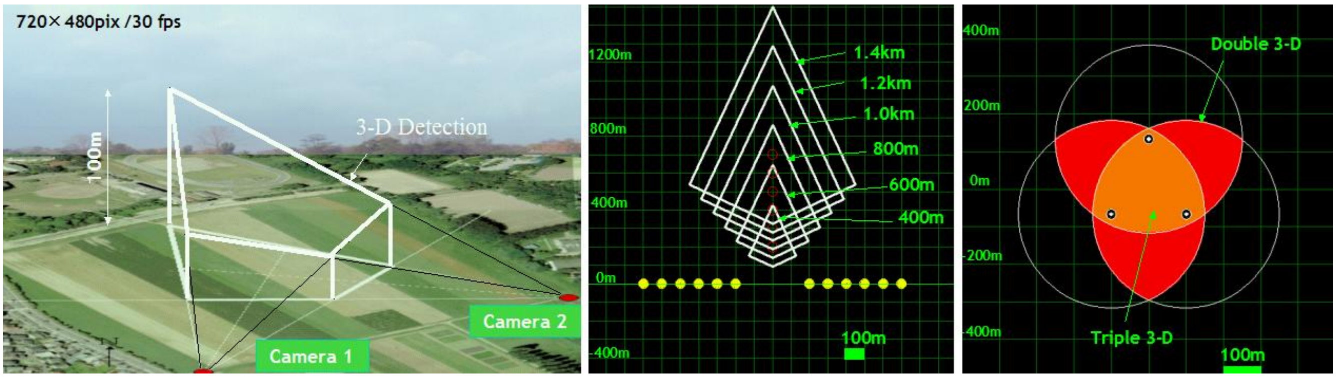
4.2 Dome-Mirror Imaging

Use of a dome-type mirror enables a camera to record the image in full 360-degree horizontal direction. As shown in Fig. 10 (a), continuous bended mirror surface captures the surrounding incident light, and reflect it to the aperture of CCD camera. A sample original image captured by the dome-mirror mounted camera is shown in (b). When the viewing axis is set downward, the ground region is projected to the central part of the image, and objects in sky to the outer circular layer. Therefore, the direction and the rough estimate of the height of a moving object are immediately determined from the coordinate in the dome-mirror image. With increase in image size, the image processing can detect smaller size of objects. Our test case is 1200 x 1200 pixel in size, and 15 fps in frame rate. The result of the test in New-Chitose airport is shown in (c), which is recorded at location C. The image presents a panoramic transformation from the original polar image so that we can recognize the view though this transformation is unnecessary when computer image processing is applied for measurement of birds. As shown in the lower picture, the differential image detects moving object which is a small aircraft running on a lane.



(a) Mirror-joint **(b) Original image** **(c) Original and differential images in panoramic form**

Figure 10. Moving object detection from dome-mirror camera at location C



(a) Shape of detectable space **(b) Detectable distance** **(c) Coupled dome-mirror cameras**

Figure 11. Arrangement of cameras for realizing 3-D bird detection

When stereoscopic measurement is performed, it will be a problem how multiple cameras are located to provide a large measurable space. Fig. 11 (a) represents the shape of the measurable space when two ordinary cameras are used in orthogonal viewing. The horizontal projection of the space becomes diamond shape which expands linearly with the mutual distance between the two cameras as shown in (b). When dome-mirror cameras are used for stereoscopic measurement, the space where three-dimensional bird position is obtained is determined as shown in (c). The circles indicate the area within the detectable limit due to pixel resolution of dome-mirror camera, the red regions means the region of three-dimensional measurement, and the orange region at the center is the region where the position is accurately computed from three cameras.

CONCLUDING REMARKS

A series of basic methods for detecting flying birds in the sky are proposed and examined. The key algorithm is to take a temporal differentiation of image brightness distribution for two consecutive images. The method is simple, yet, the most feasible in realizing on-time monitoring of bird. Moreover this method has robustness for hours and weather differences as we have demonstrated by statistics from large number of sampling. The application to aerodrome at New-Chitose airport, Hokkaido, Japan, has shown the availability of the present method.

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