3D Flight Path Tracking of Butterflies by Image Processing

Case Study

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Abstract – *The first results of an interdisciplinary cooperation of the UoAS Würzburg-Schweinfurt, the Faculty of Electrical Engineering and the University of Würzburg, Biozentrum, are introduced in the paper. The principal goal is to identify the abilities, motivation, and decision rules underlying the movement of small butterflies (Polyommatus Icarus, Common Blue) and to develop a 'cognitive' movement model. The described part of the UoAS Würzburg-Schweinfurt is the record of movements by installing high resolution video cameras in a large outdoor flight cage, as well as developing software for 3D path tracking.*

Keywords – *movement trajectory, stereoscopic 3D camera, video tracking.*

1. INTRODUCTION

To study the effects of internal state and external factors on organismal movement by empirical and theoretical investigations, an experimental approach was tested. Perception, memorized knowledge and the internal state of individual butterflies affect movement decisions at a fine spatial-temporal scale. Movement trajectories of butterflies with known status (age, mating status, body mass, egg-laying history, hunger level) and known previous experience about the environment (memories) are recorded by high resolution video cameras in a large outdoor flight cage. Influences from manipulating the spatial distribution of critical resources (e.g., nectar and host plants) within the flight cage are recorded and provide an unprecedented opportunity to study, inter alia, how movement decisions of individuals are influenced by their energy budget [1-5].

2. FLIGHT CAGE AND CAMERAS

To gain reliable information about the movements of butterflies, a near natural environment in a large outdoor flight cage is provided in the experiment. An area of some 100m2 supported with flowers, dummy flowers and grass, as well as markers for image processing, is monitored by means of several stereoscopic 3D cameras. The cameras are either one S3D camera, or, as an option, two 2D cameras are mounted on a rig. Fig. 1 shows the placement of cameras.

The footprint covered by one S3D camera is about 1.2m x 2.0m for 1280 x 720 at HD resolution. Or, using two 4k cameras on a rig, an area of 6m x 3.5m can be observed. The 4k resolution is 3840 x 2160 pixels. This yields a number of 50 S3D-HD or 10 S3D-4k cameras for the whole flight cage. Lateral resolution is ca. 1.6mm in x- and y-direction. Due to 3D disparity processing, z-resolution is smaller, but a remaining height deviation of +/- 25mm fulfills the given requirements.

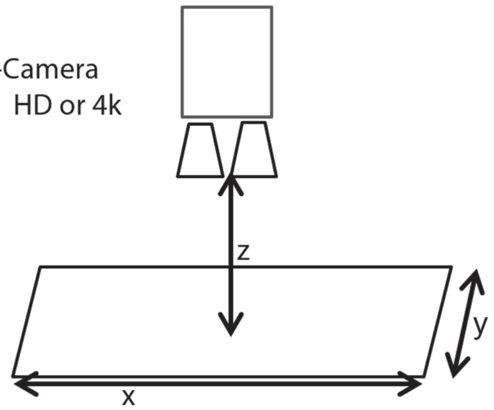

Fig. 1. Placement of cameras

The data rate at a 60 fps frame rate for each S3D-4k-camera combination is 18GBit/s (uncompressed raw data) or, recorded on an SD card in MPEG-4 or HEVC standard, 40Mbit/s [6]. Screening duration is up to 30 minutes.

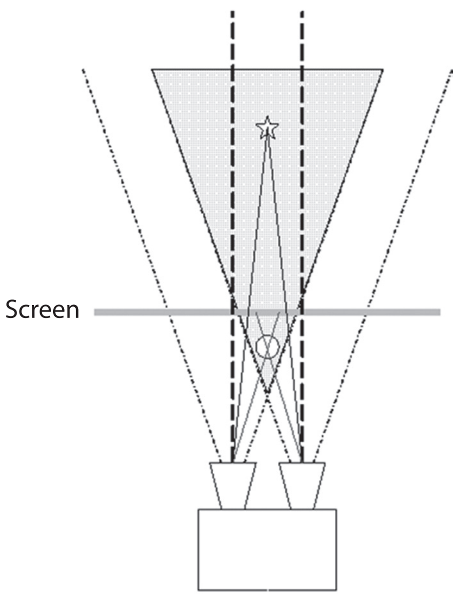

Fig. 2. S3D-Camera and disparity of objects in front and behind the screen

Fig. 2 and Fig. 3 illustrate the variation of disparity of objects in front, on, and behind the screen. The distance is easily calculated using stereo base and screen position, as well as the included markers [7-10].

As an example, Fig. 4 shows the results of a 3D analysis done by the OMNITEC OTR 1001 TV test system. The cross marks the position (the x-coordinate in meters) of the test object related to the position of the screen. The position of the screen (the line in the middle) and the save acting area for 3D production (left and right borders) are also marked.

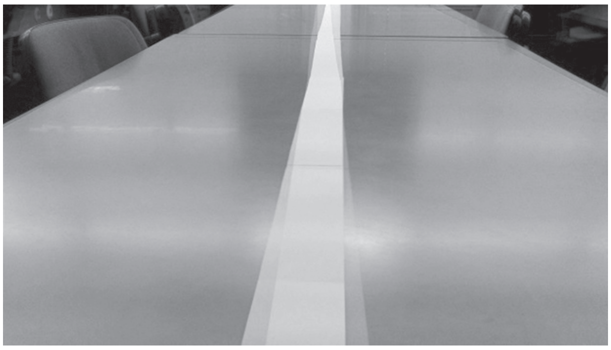

Fig. 3. Disparity (red and green stripes) varying with the distance from the screen

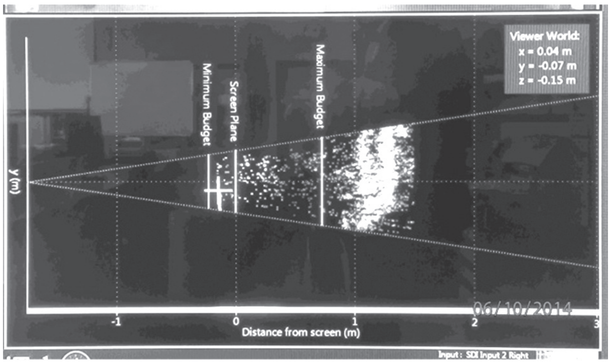

Fig. 4. OMNITEC OTR 1001 3D Analysis

3. DIGITAL IMAGE PROCESSING

Detecting a butterfly and tracking its position is done by means of digital image processing. The nearly static background (grass and flowers) is removed by the prediction filter and the focus is laid on moving parts in the pictures. Testing colour and shape supports detection of the butterflies. Software tracks the paths and calculates the coordinates of the trajectories.

4. FIRST RESULTS

In a preliminary study conducted in summer 2014, a 'proof of concept' test for monitoring butterfly movement using consumer type stereoscopic 3D-HDTV video cameras was carried out successfully. We recorded flight trajectories of *Polyommatus Icarus* in an outdoor cage (8x8x3m) with a bottom screening area of 4m x 2m.

Video filming was done against a natural and heterogeneous background (a meadow cut to ca. 15cm length). Tests showed that on account of the small size of *P. Icarus* (wingspan 25 mm), camera resolution of approximately 1.6mm per pixel in x- and y-direction is appropriate for tracking. What is also necessary is the high camera frame rate of 60fps. The 60fps sufficiently sample the 20 wing beats per second of a little butterfly. As an example, Fig. 5 shows a short section of the calculated x-y trajectory of one of the butterflies.

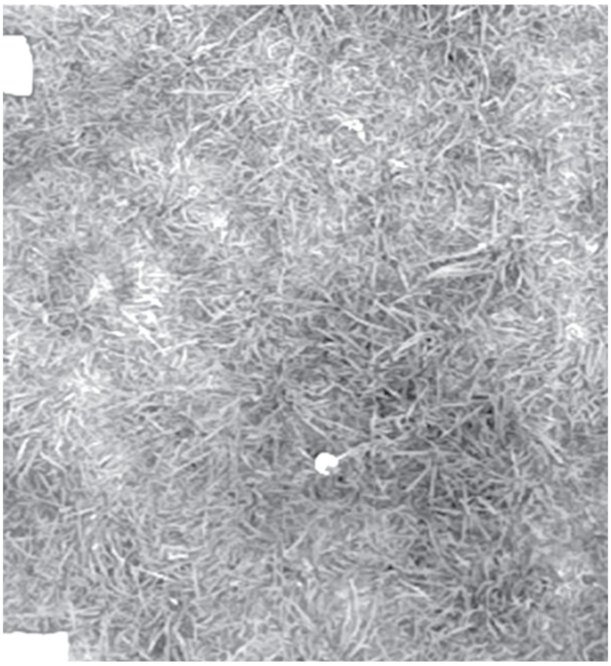

Fig. 5 Example of a flight trajectory

5. CONCLUSION AND LOOK AHEAD

The results recorded in a small open air flight cage, using consumer S3D-HDTV cameras are promising. But for a large cage, high-end amateur 4k cameras will be used. The better spatial resolution yields a by far smaller amount of cameras.

Furthermore, the tested software for image processing and identification of butterfly movement trajectories shall be improved as well as data management. Options, such as marking and naming of individual butterflies and other objects like flowers, will be included. Finally, statistical evaluation of the filed results and development and validation of the computer-aided 'cognitive' movement model are carried out in Biozentrum of the University of Würzburg.

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