Advantages and limits of a video multitracking system for quantification of individual behavior in a large fish shoal

J. Delcourt[1], C. Becco[2], N. Vandewalle[2], and P. Poncin[1]
[1]*Behavioral Biology Unit: Ethology and Animal Psychology, Department of environmental Sciences & Management, Faculty of Sciences, University of Liège, Belgium, Johann.Delcourt@ulg.ac.be*
[2]*Group for Research and Application in Statistical Physics (G.R.A.S.P.), Department of Physics, Faculty of Sciences, University of Liège, Belgium*

Introduction

Video multitracking systems able to track animal groups have recently been developed but are not yet in common use. To study fish shoals, the group sizes exceed rarely some individuals. This is insufficient to study schools of real size, which often contain hundreds of fish. Moreover, when the trajectories of two fishes cross each other and their images coincide (termed occlusion), these programs are usually unable to attribute the correct identity to each fish after they uncross, or separate. Others individual multitracking systems able to track a large number of targets have been produced. Unfortunately, a similar system does not yet exist for fish tracking. Moreover, the behavior of fish is more complex because the apparent image of the fish is highly variable and the direction and speed of fish displacements can change very quickly in terms of time and magnitude.

Delcourt *et al.*[1] have developed a 2D multitracking system to quantify the schooling behaviors in fish using a laboratory approach. A dynamic predictive model is based on the previous measures of velocity vectors [2]. The system's ability to correctly track a large number of individuals (up to 100) in the same arena is introduced.

Materials and methods

We worked with images converted to JPEG format and eliminated the background noise with a reference image of the arena with no fish. Then a range of grey-scale characteristics of the image of the fish was detected. The detected pixels were converted to a binary format that was usable by our tracking program.

We estimated the capacity of our system to assign the correct identification to each fish compared with the human eye. We define the Recognition ratio of individual fish = $A*T_O + B*T_S + C*T_N$.

(T_O = number of identity assignments in the context of occlusion/total number of identity assignments; T_S = number of identity assignments when separation/total number of identity assignments; T_N = number of identity assignments in other cases /total number of identity assignments; A = successful identification ratio when there is occlusion; B = successful identification ratio when there is separation; C = successful identification ratio in other cases).

Results

The ratio of successful identifications varies in relation to the identification events (see table 1). The greatest difference appears between the cases of occlusions and no occlusions. When there are no occlusions, the program is very efficient (close to 100%). With a good image rate, if there is no contact between the images of two fishes, there is no problem identifying each fish. When occlusions occurred, two situations were distinguished: during the occlusion and the subsequent separation of the images of the two fish (end of occlusion). During the occlusion, we considered that the spot (the image of the two superimposed fish) has a double identity from both fish, making the identification nearly always correct. In the separation situation, the ratio of successful identifications ranged from somewhat good (83%) to poor (close to 50%). This was the main cause of identification errors. Two situations could occur.

In the first situation, the program did not detect the separation. A fish retained the double identity and the second fish had no identification number. The second was an orphan if the program searched for a constant individual number. When the program provided for the appearance of a new individual during the tracking, a new identification number was assigned to the orphan fish. In this case, the identification error was easy to detect. Moreover double identity (occlusion) is a short periodic state. If a fish retains a double identity over more than 0.5s (see figure 2), double identity can be considered uncertain. Knowing this characteristic makes it possible to automatically detect misidentification when the program fails to detect a separation.

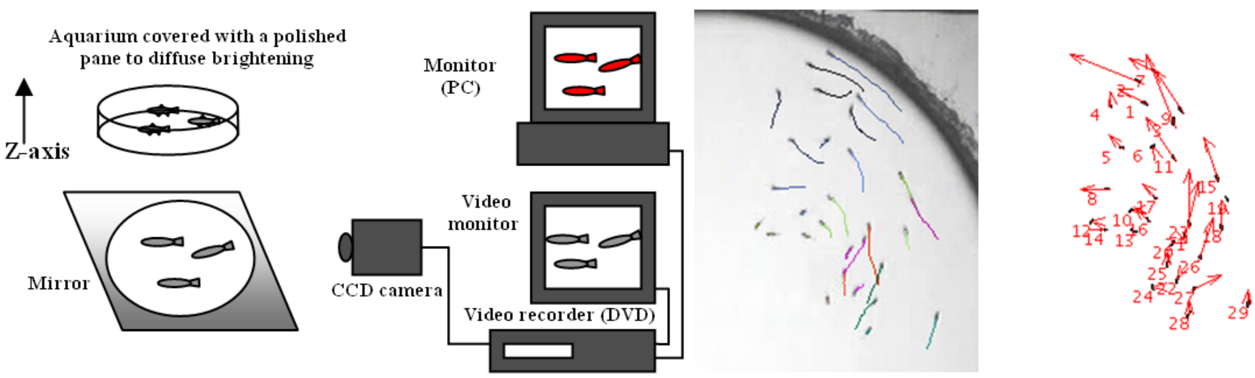

Figure 1. *Left: Diagram of the multitracking setup. A CCD camera filmed a mirror reflecting the bottom of the circular tank. Right: example of tracks (detail of the arena, period of 1 sec) and the same image with individual assignments and velocity speed.*

***Table 1**. Ratio of successful identifications in relation to the number of fish (n= number of identification events).*

Nb of fish	Ratio of successful identifications			
	Occlusion	Separation	Others	Total
10	100 (*n* =156)	75 (*n* =21)	99.97 (*n* =9822)	99.92 (*n*=10000)
20	100 (*n* =277)	73.3 *n* =40)	99.99 (*n*=19683)	99.93 (*n*=20000)
30	100 (*n* =259)	71.4 (*n* =37)	99.96 (*n*=29704)	99.93 (*n*=30000)
40	100 (*n* =203)	63.6 (*n* =29)	99.97 (*n*=39767)	99.94 (*n*=40000)
50	100 (*n* =1035)	68.4 (*n*=149)	99.97 (*n*=48816)	99.88 (*n*=50000)
60	100 (*n* =554)	50 (*n* =40)	99.22 (*n*=59406)	99.20 (*n*=60000)
70	100 (*n* =1219)	72.7 (*n* =176)	99.98 (*n*=68605)	99.92 (*n*=70000)
80	100 (*n* =998)	55.5 (*n* =144)	99.78 (*n*=78858)	99.71 (*n*=80000)
90	100 (*n* =1214)	44 (*n* =220)	99.89 (*n*=88566)	99.75 (*n*=90000)
100	100 (*n* =993)	62.5 (*n* =180)	99.88 (*n*=98827)	98.83 (*n*=100000)

Second, identities could be inversed: after separation, each fish retained the identity of the other individual. In this case, it was very difficult to automatically identify the error.

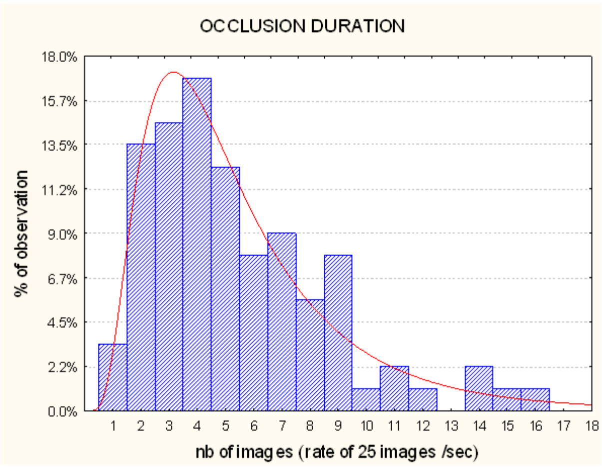

***Figure 2**. Occurrence of occlusion duration. The rate of images is 25 images per second. The fit corresponds to a lognormal curve (μ=1.52, σ = 0.61). (n=200).*

Discussion

In statistical tracking, in which the identity of a fish is important for only a short time (e.g., to measure the individual's speed), but not in the final analysis, the program is very efficient, with more than 99% of the individuals successfully identified. On the other hand, for longer duration rigorous individual tracking, a single assignment error has a dramatic effect on the study. Visually verifying the trajectories after crossing events is feasible when fish density is low, but becomes significantly less so as the numbers of fish increase. The computer can help the experimenter by indicating the occurrence and position of a crossing event. However the separation rate is generally less than 0.1% of the total number of attributions and the visual expertise is not a significant work.

Consequently, in both statistical and rigorous individual tracking, this system allows the experimenter to gain more time by measuring the individual position automatically. It can also analyze the structural and dynamic properties of an animal group with a very large sample, with precision and sampling that are impossible to obtain with manual measures.

References

1. Delcourt, J., Becco, Ch., Vandewalle, N. & Poncin, P. (2006). Comparing the *EthoVision*® *2.3* system and a new computerized multi-tracking prototype system to measure the swimming behavior in fry fish. *Behavior Research Methods* **38(4)**: 704-710.
2. Delcourt, J., Becco, Ch., Vandewalle, N. & Poncin, P. (2005). A new automatic video multitracking system able to follow a large school. *Proceedings of Measuring Behavior 2005, 5th International Conference on Methods and Techniques in Behavioural Research* (*Wageningen, 30 August- 2 September 2005)*, pp.405-406.