Swistrack –an open source, software package applicable to tracking of fish locomotion and behaviour

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Introduction

PC based tracking of fish is a valuable method for monitoring fish behaviour in experimental tanks. Tracking of fish movements enables quantification of variables including swimming speed, acceleration and directionality of movements as well as the examination of locomotory patterns and kinematic variables during swimming, to mention a few. Swistrack, a free and downloadable software package developed by the Distributed Intelligent Systems and Algorithms Laboratory (DISAL) and the LPM Vision Group at EPFL Lausanne, Switzerland (available from www.sourceforge.com) is widely used for tracking robots, humans and other animals (Correll et al., 2006). Accordingly, Swistrack can be easily adopted for the tracking of fish.

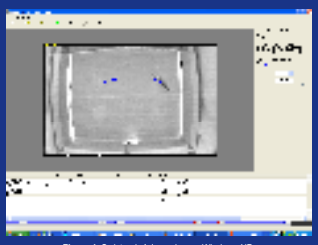

Figure 1. Swistrack 4.1 running on Windows XP

Tracking Individual Fish

Tracking of individual fish within an experimental arena is perhaps the simplest of tracking designs. Fish occupying a tank of markedly different colour or contrast are easily identifiable by the software and can be tracked extremely accurately.

The video image is converted to the channels of choice (colour or grayscale) and processing steps performed, ultimately resulting in tracking of the geometrical centre of fish mass.

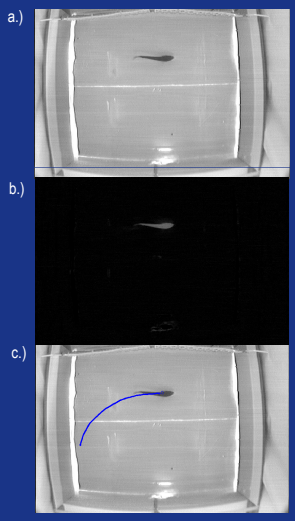

Figure 2. (a) A raw camera image of a juvenille kingfish (*Seriola lalandi*) swimming in a behavioural arena. (b) The same image with an adaptive background subtraction overlaid, identifying the sole moving object (i.e. the kingfish).(c) The same image being tracked (i.e. x,y coordinate generation) with a tail indicating the most recent 10sec of prior activity.

Setting up the Tracking Environment

With swistrack a video stream (USB, Firewire or GigE camera) or recorded video file (.avi format) can be analysed.

After video input, a 'pipeline' of components is constructed that will edit components of the video image, ultimately resulting in a calculated track of the fish. The types of editing involved may entail:

- A background subtraction
- Thresholding – pulling out pixels resembling the object to be tracked, converting them to a binary image
- Particle detection – where the predominant blob of pixels is selected for tracking. Filters can limit the blob to a select pixel size range
- Tracking component – where the geometric centre of the fish is converted to a x,y coordinate
- Output – where the x,y coordinate and accompanying data be streamed across a TCP connection or written to .txt file

Figure 3. .Illustration of a basic camera tracking setup.BA: Behavioural arena, Sc: Screen, V: Video Camera, PC: Computer

Tracking Multiple Fish

Tracking of multiple fish within an experimental arena is difficult owing to overlapping swim trajectories causing a 'track exchange' between individuals. To overcome this problem, individuals can be differentiated using coloured marks so that the tracking software will recognise and attribute tracks specifically to the individual. The authors are currently in the process of writing a component into swistrack that can differentiate up to 10 fish in an experimental arena.

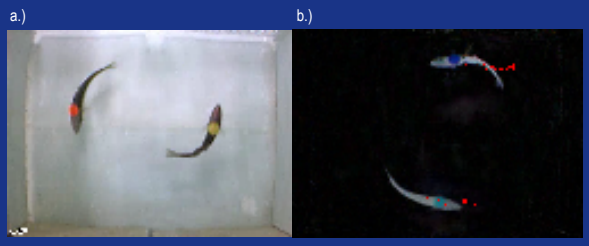

Figure 4. a) Raw image of fish with marks attached to the fishes dorsal surface, b.) Individual specific tracking of coloured marks

Tracking multiple tags

Attachment of marks of significantly different contrast to the animals surface provide points for tracking. Specific marks acting as points of reference enable determination of amplitudinal or periodical variables of interest. For example, tracking of tail beat frequency can be used for estimating metabolic expenditure of the swimming animal (Steinhausen and Steffensen 2005, Lowe et al. 1998, Webber et al., 2001).

Geometric variables can also be determined when two or more marks are present. For example, trigonometric determination of tracked coordinates can define the fishes directionality in euclidean space. Enabling determination of variables such as orientation, turning angle and turning rate.

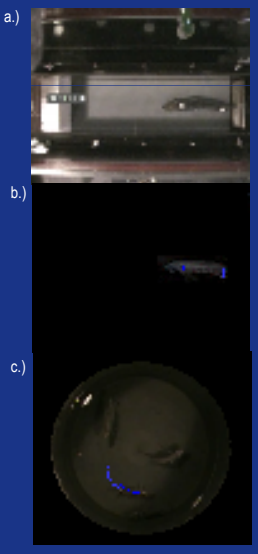

Figure 5. (a) A raw image of a marked fish swimming in a flume (b) marks being actively tracked during swimming (c) two marks on a routinely swimming fish being tracked for determination of directional vectors

Custom Designing Tracking Protocols

The open source nature of Swistrack allows users competent in the C++ programming language to modify and design additional tracking protocols. One example is the behavioural thermoregulation setup written at the Leigh Marine Laboratory (Khan, Atkins and Herbert, unpublished).

In this study, fish movement is tracked within a shuttle box designed to present a warm and cool water environment on either side of the box. Movement across the shuttle box threshold, activates either a heating, or chilling unit, warming or cooling the body of water the fish is occupying. Using this design, the fish is capable of behaviourally regulating their temperature. Tracking data as well as temperature data is recorded for output. Continuance of this experiment for prolonged periods identifies the thermal range that the fish preferentially occupies.

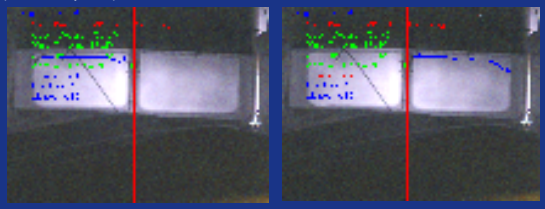

Figure 6. (a&b) Behavioural thermal regulation tracking design

Conclusions

Swistrack provides a software package that can be utilised for the tracking of fish swimming in an experimental arena. Numerous approaches to tracking can be pursued, involving the tracking of the whole animal, or tagged points of interest. The open source nature and ability to incorporate additional tracking protocols makes Swistrack a powerful tool for PC based tracking of fish locomotion and behaviour.

Acknowledgments

The Authors would like to acknowledge help from the following individuals, Neill Herbert, Tabea Salewski, Elliot Brown and Bjorn Tirsgard.

Author DC would like to thank the Society for Experimental Biology, the Fisheries Society of the British Isles and The New Zealand Marine Sciences Society for financial help enabling presentation of this poster at the Fitfish symposia, Barcelona 2010.

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