SEVENTH FRAMEWORK PROGRAMME
THEME ICT-2007.8.3 - FET proactive 3
"Bio-ICT convergence"

Grant agreement for: **Collaborative Project**
(small or medium-scale focused research project)

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Project Deliverable D8.3:

Report on artefact control via lamprey signals and on influencing the lamprey behaviour via artefact signals

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1. Introduction

As indicated in the second periodic project report the original plan to use recording of the reticulospinal signals mediating the steering command from the brain turned out to be technically difficult, since the signal was too noisy. During the last period we have looked in some detail on the biological steering signal as recorded from muscle segments along the body in interaction with the SSSA team (Capantini et al, unpublished). These signals can be used for controlling the lamprey artefact after adaptation to the robot control system.

We have also conducted experiments on the lamprey robot, which swims with biological principles with a phase lag along the body.

2. Signals Recording

Electromyographic signals (EMG) has been recorded from along the body of lamprey, during active swimming. The goal was to find out a specific pattern describing the steering movement, in particular turning episodes. The pattern obtained have been filtered and adapted for the robot control.

2.1. Methods and experimental setup

Adult lampreys (Lampetra fluviatilis, 25–30 cm long) were used in the experiments. The specimens was anesthetized before perform the surgery. An amount of three bipolar EMG electrodes per side (flexible wires of 0.15-mm diameter) were inserted in the 3 different dorsolateral region: rostral (behind gills region); middle (in a more ventrally position) and caudal (between the dorsal fins). Moreover, 3 plastic markers were sewed at the same distance each other (about 7 cm, depending n the total length of the specimen) as tracking points. The swimming steering behaviour was studied in a shallow tank (100 x100 cm, 10-cm depth) (Fig. X). All the experimental session was recorded from an High Speed video camera (300 frames/s) and analyzed with a video image tracking software (ProAnalyst® Professional Edition).

The EMG electrodes were connected by a long flexible cable to the inputs of AC amplifiers. The EMG signals were amplified, rectified, smoothed (time constant: 10ms). The EMG and videorecordings were synchronized by light flashes recorded simultaneously by both systems.

The most representative recorded episodes of turnings have been selected and then analyzed with an image tracking software, utilized as points for tracking the head and the three markers placed all along the body (Fig. 1).

This allowed us to obtain the trajectories during turning movement, and to calculate the body curvature during a sequence of swimming (forward swimming before and after turning, included the turning itself). Trajectories and image analysis were made using a frame rate of 30.

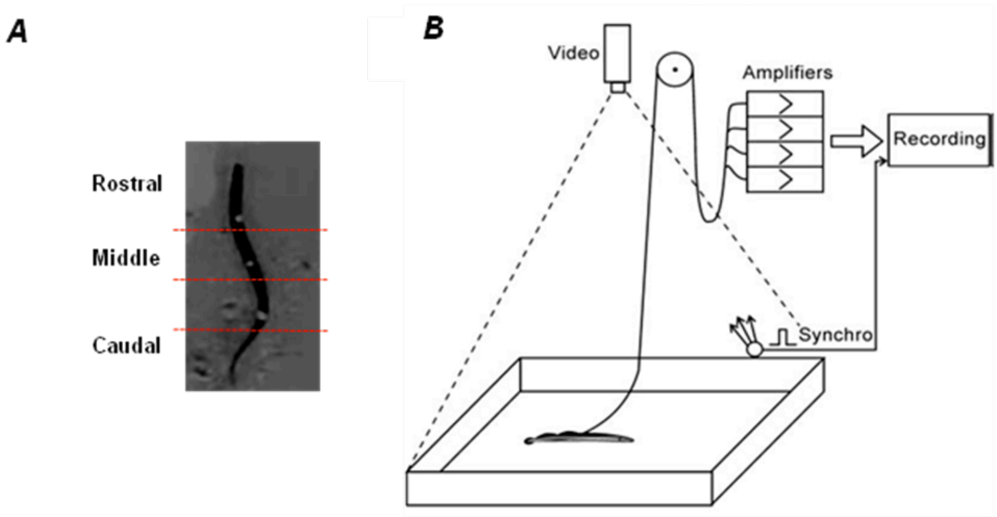

Figure 1*. Experimental setup. A: a lamprey specimen before experiment. The red dotted lines indicate the position of electrodes implantation. B: arrangement for parallel recording of kinematical and electromyographic (EMG) data. Video- and EMG recordings were synchronized by light and electrical pulses recorded simultaneously by the 2 systems (Synchro). (modified from Islam et al. 2006)*

2.2. Results: steering behaviour

The correlation between EMG recordings and data set of the trajectories, provided a general qualitative description of the steering behaviour of lamprey during free swimming (Fig.2).

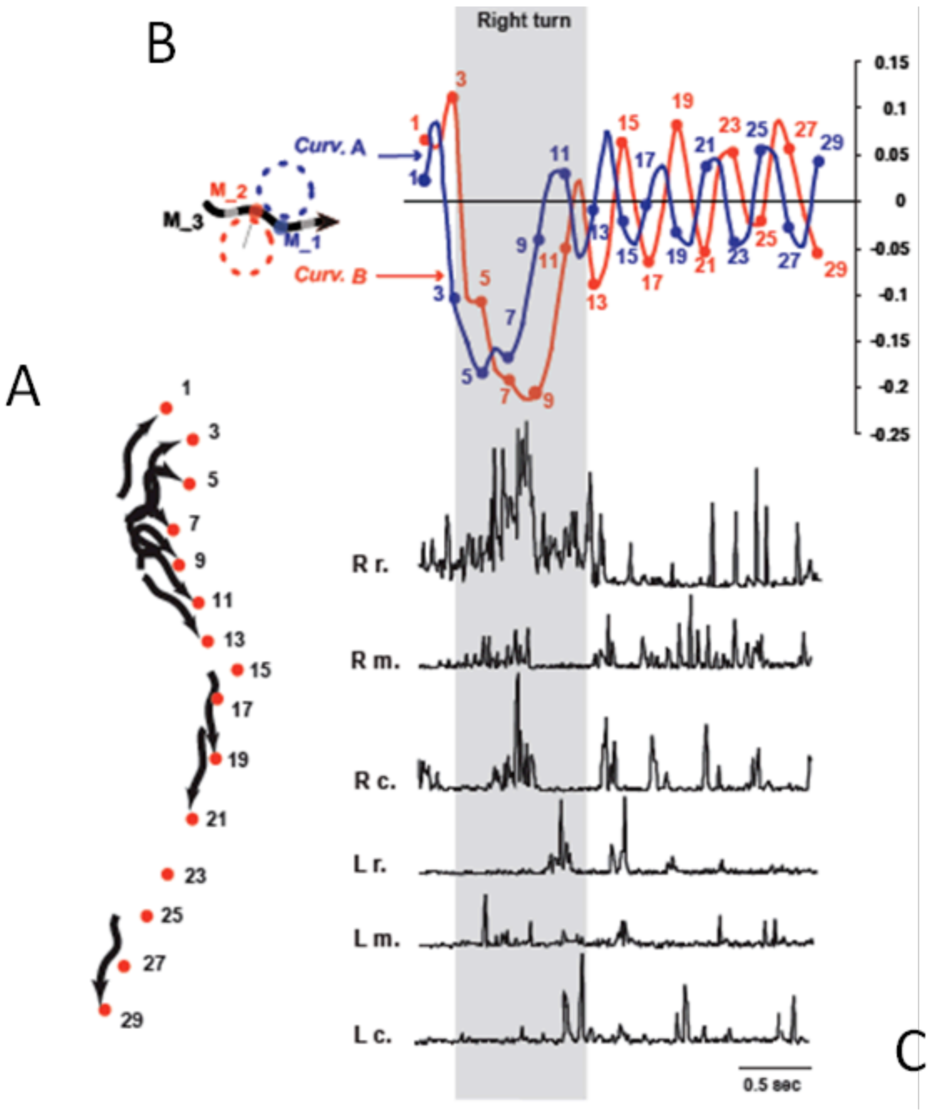

***Figure 2**. Correlation between kinematics and EMG activity during a right turn followed by forward swimming. A: Shapes of body midline in a sequence of 15 frames; red dots outline head trajectory. B: Body curvature in two different points (marker 1: M_1, and marker 2: M_2). The measuring of curvature was made per each frame: the curvature at the 2 points was defined as Cur =(1/R) where R is a radius of the circle drawn through the point of recording (M_1 and M_2) and 2 adjacent points. C: For the same period, left and right EMG recordings at three sites (marker 1, 2 plus marker 3) respectively of rostral, middle and caudal region.*

2.3. Comparison with the artefact

We analyzed a left turn episode performed by the artefact, and then we compared its body curvature with that of lamprey. As shown in the figure, the comparison between two plots points out a similar trend (Fig. 3).

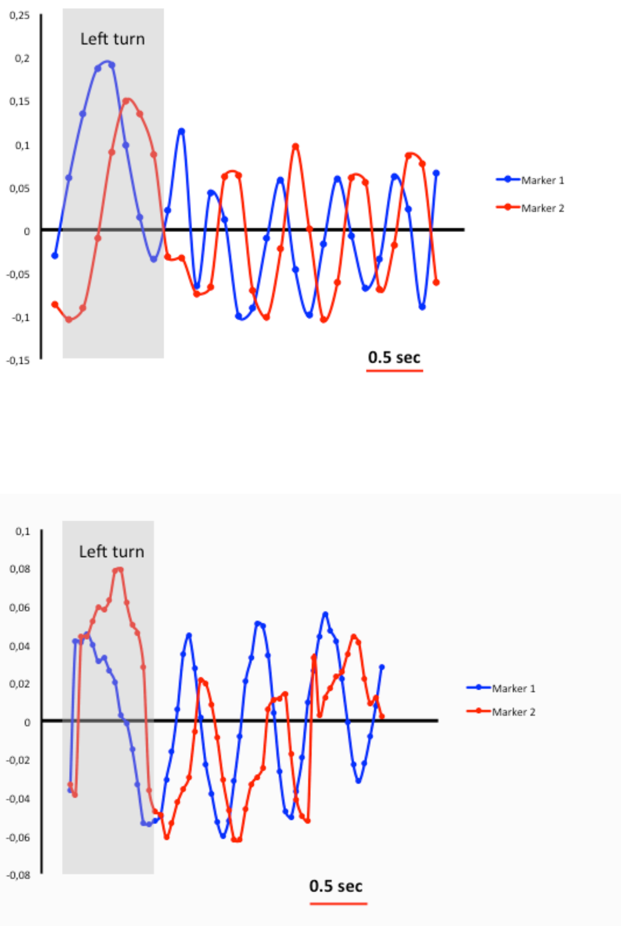

Figure 3. *Comparison between body curvature of lamprey (above) and the artefact (below). Both of plots show sequence of left turn followed by forward swimming of about 3 seconds. (See figure XX for discussion about body curvature).*

3. Experimental session with the artefact

During the last meeting between SSSA and KI Team placed in Stockholm at KI, experiments with artefact and lamprey have been performed in a metal frame swimming pool (ca. 3 meters in diameter). In order to have a comparison between artefact and lamprey in real time, they were let to swim together inside the pool (Fig. 4).
All the trials were recorded with a webcam (Microsoft®, wide angle F/2.0, 720pHD, 30fps).

The frequency of the locomotion of the swimming lamprey is in a range from 0.5 to 10 Hz and the current version of the lamprey robot is not able to reach the level of locomotor activity elicited by its biological counterpart. The speed of locomotion can be changed by modifying the frequency of oscillations, and there is a linear relation between frequency of swimming and speed of locomotion up to 0.6 Hz with maintained amplitude of the locomotor movements and a constant phase lag.

The artefact can also be steered and turn in an efficient way in a mode similar to the biological model. In fact the steering signal for the artefact is designed in a way that corresponds to the myoelectric pattern used by the orienting lamprey. In order to have stable swimming it is important that the head does not oscillate with a large amplitude since this puts very heavy demands on the visual system and impedes the locomotor movements. We therefore have implemented a head stabilization to decrease the head oscillations in two ways: the first segment of the body has been operated in antiphase with the subsequent segment, and in addition we have enhanced the extension of the profile of the head in order to enhance the lateral resistance.

The visual input from the two eyes (CMOS cameras) on the head convey a stereo image which is used to control the swimming direction of the artefact. From these signals the lamprey artefact can discriminate objects (e.g. light sources but also other targets). It can this swim towards different targets in an autonomous way and cal also be "instructed" to avoid objects.

Figure 4. *Snapshots extracted from video recordings made during experimental session.*