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)

Project acronym: LAMPETRA
Project full title: Life-like Artefacts for Motor-Postural Experiments and Development of new Control Technologies inspired by Rapid Animal locomotion

Grant agreement no.: 216100

Project Deliverable D6.3:

Second prototype integrated

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Summary

1. Introduction

This document is accompanying the deliverables of the second artefact. The deliverable D6.3 is consisting of this document (R) and the prototype (P). The deliverable D6.3 is of “O” nature, being represented by the artefact, the components embedded and the pictures and videos about the artefact tests, demonstration and dissemination event.

The integrated components, hardware, software and mechanical are described in other documents, namely:

- deliverable D4.4: *Components for second artefact prototype ready for integration*
- deliverable D5.2: *Control HW and SW for the second prototype*

The pictures included show an overview of the artefact during operation such as swimming tasks (free swimming or tracking/avoidance), motion tests and the preliminary set up of the robot trunk made in air in order to observe the “muscle-like” performances and also the CPG frequency transmission. The relevant videos listed below are included into the CD.

As indicated in the table below, The second “lamprey-like” prototype can swim for about five hours at circa 0.5 body length per second using approximately 10 W. All changes and improvements done during the design and the fabrication of the second prototype made it possible to have a robotic system with better performances than the previous one.

	First prototype	**Second prototype**
Robot size	0.86 m, diameter 54.5 mm	length 0.91 m, diameter 54.5 mm
Swimming speed	0.4 body length per second	up to 0.5 body length per second
Power consumption	4 W	10 W
Turning radius	50 mm	75 mm
Autonomy	3 hours	5 hours

Table 1: Comparison of characteristics and experimental performance between first and second prototype.

2. Experiments

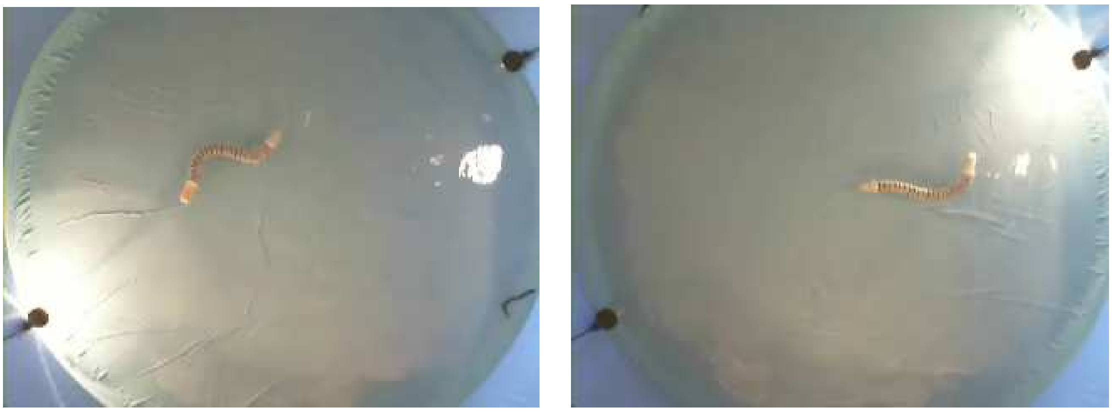

Figure 1: *Test and experiments on object tracking*

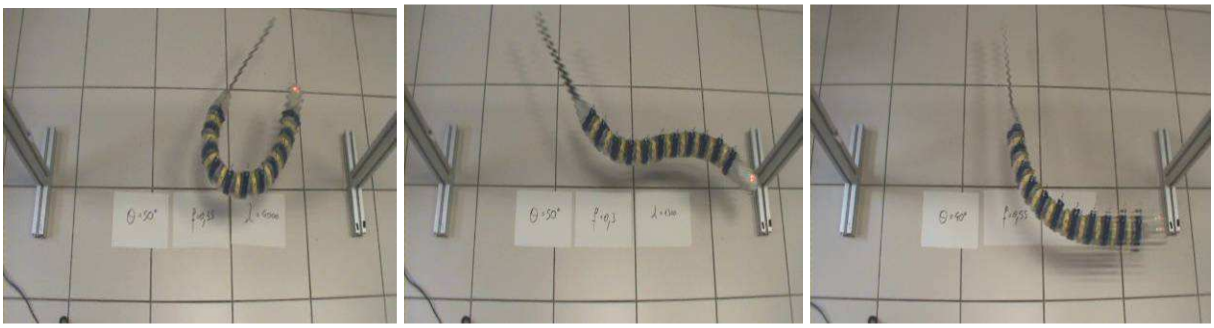

Figure 2: *Experiments for tuning phase lag, resonance frequency and stationary travelling performances.*

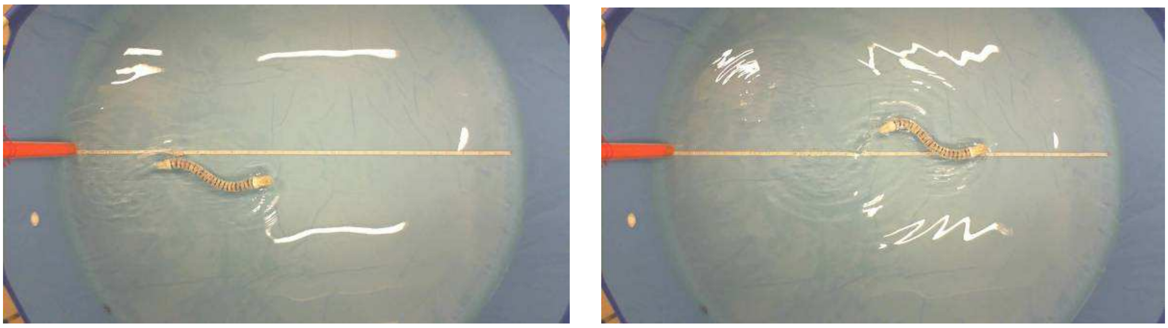

Figure 3: *Experiments on swimming with or without head stabilization*

Figure 4: *Experiments on turning and flexibility*

3. Main tests and demonstrations

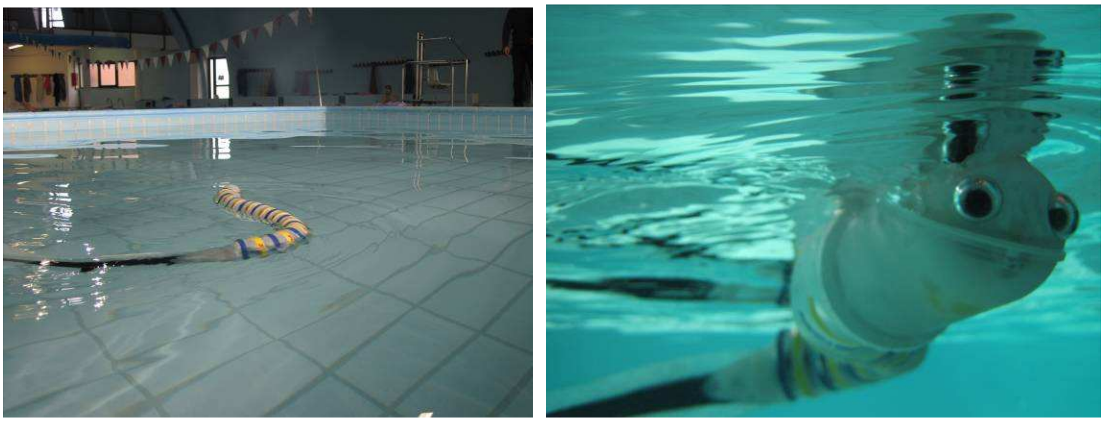

Figure 5: *December 2010, LAMPETRA SSSA group; experiment at the swimming pool of Pontedera. The artefact swim test requires free space in order to evaluate qualitatively and quantitatively the locomotion forward task.*

Figure 1: *February 2011, LAMPETRA SSSA group; experiment at the KI. Experiments on vision system, object tracking and free swimming.*

Figure 2: *May 2011 SSSA Lampetra Team at FET 11*

Figure 8: *April 2011 LAMPETRA artefacts at the International Workshop on Bio-Inspired Workshop*

4. Videos

Videos about the first prototype testing and swimming can be found into the multimedia CD enclosed to the Deliverable Materials.

Video 1	*Free swimming of the artefact*
Video 2	*Light tracking (autonomous behaviour)*
Video 3	*Underwater video of free swimming*
Video 4	*Tests on travelling performances - robot suspended (Lambda 10000 f 0,1)*
Video 5	*Tests on travelling performances - robot suspended (Lambda 1000 f 0,3)*
Video 6	*Tests on travelling performances - robot suspended (Lambda 1000 f 0,35)*
Video 7	*Tests on travelling performances - robot suspended (Lambda 1000 f 0,45)*
Video 8	*Forward swimming without head stabilization (A50_f0.6_L1220)*
Video 9	*Forward swimming with head stabilization (A50_f0.4_L1220)*

5. Novel lamprey and salamander robot prototypes

SSSA and EPFL are working on two novel robotic artefacts in order to explore richer motor skills like proposed in the LAMPETRA project. Prototypes are currently under development and will be ready in no more than a month.

5.1. The third lamprey-like robot prototype

The last and second prototype developed during the project and presented in these deliverables is source of pride for the consortium: an artefact highly bioinspired and with good performances that moves in a real adaptive way as a sort of natural "resonant" system, in which mechanical properties of skeletal apparatus and actuators stabilize the system during locomotion. Binocular vision system and sensors distributed along the whole body of the prototype also ensure a closed loop control allowing autonomous behaviours during the completion of tasks such as the object tracking or the obstacle avoidance. However, mainly due to problem with wireless communication, this artefact is not able to swim in 3D. In fact, this kind of communication allows the robot a greater range of movement, but at the same time, it represents a big issue in the water/underwater environment. This is due to the air/water interface and to the water medium properties: these add noise to the transmission and cause channel corruptions when robot swims under the water surface. Both frequency used and transmission power influence these events. In general, lower frequency signals can travel deeply in the water, but the baud rate is reduced. This creates problems both during data acquisition (sensors, cameras, etc ...) and when commands are sent at the artefact when it is tele-operated.

In conclusion the prototype described and presented in these deliverables is a sort of compromise between the development of a completely bioinspired artefact and technological limits due to the transmission.

However, in order to overcome these limits, SSSA is developing a new lamprey-like prototype. It has all features of the previous one, but it is able to swim freely under the water surface (3D swimming) changing its buoyancy thanks to a cam system.

Figures below show mechanical concepts of the new prototype and some stages of its assembly.

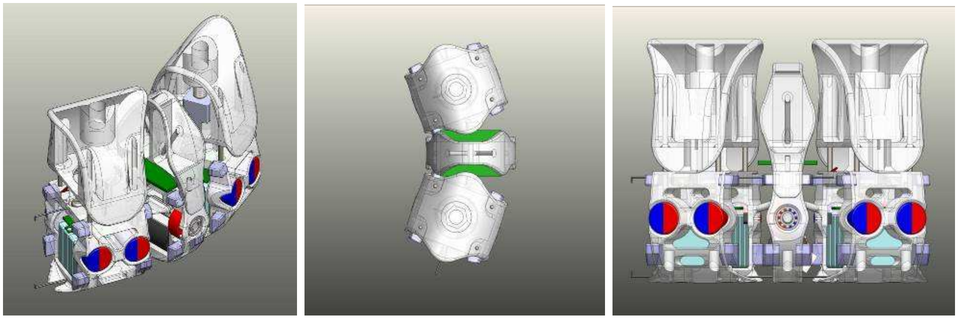

Figure 9: *Mechanical concepts of new vertebras for the 3D swimming robotic lamprey artefact*

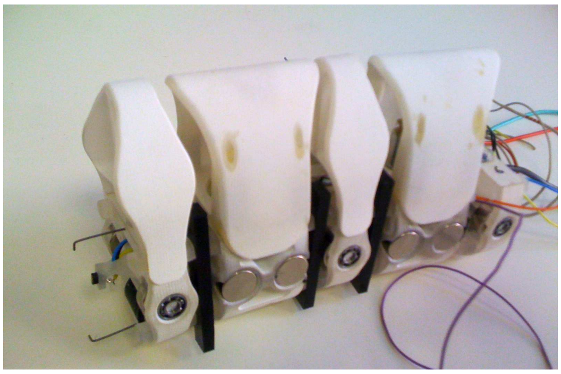

Figure 10: *New vertebras assembling for the 3D swimming robotic lamprey artefact*

5.2. A novel salamander robot prototype

A novel salamander-like prototype has been developed. This new prototype enables us to study richer motor skills. This has been possible due to several novel features: (1) the morphology is an exact scale-up of the skeleton of a real salamander and (2) the new prototype has all the DoFs needed to replicate the kinematics as recorded from X-ray cinematography including multi-segmented limbs (compared to the rotational limbs of the previous prototype) and optimized resolution of the spine.

The new salamander robot (Figure 11) has the following enhancements respect to the previous one:

- Development and test of more sophisticated limb designs compatible with the existing salamander-like prototype. More precisely, the folding limb design increased the stepping speed and swimming efficiency. The limb design with flexible fingers was evaluated but proven to be effective (speed increase) only at frequencies less than 0.6 Hz.
- Study of the 3D kinematics of the skeleton of real salamanders providing insights for the exact movement of each body part.
- Modeling and optimization of the number, topology and position of each degree of freedom needed to replicate the motion of the recorded skeletal movements for stepping and swimming.
- Development of a physical and simulation model of a new salamander-like platform which is capable of performing more complex motions as it is able to replicate the skeletal motions of the real salamander.
- Control hardware was integrated in the new platform.
- Control software, based on the X-ray analysis, was also integrated in the physical model.

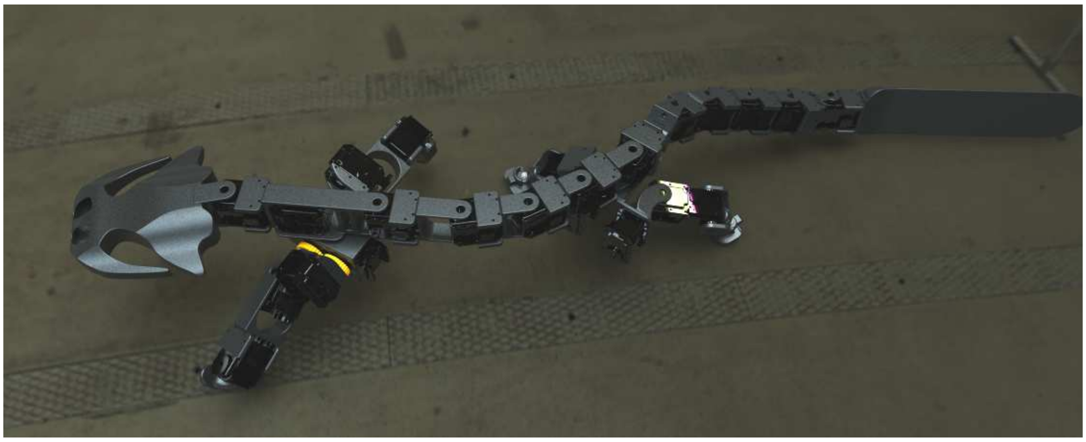

Figure 11: *CAD drawing of the new salamander-like prototype inspired by the skeletal movements of salamanders.*