Model of perception by the electric sense

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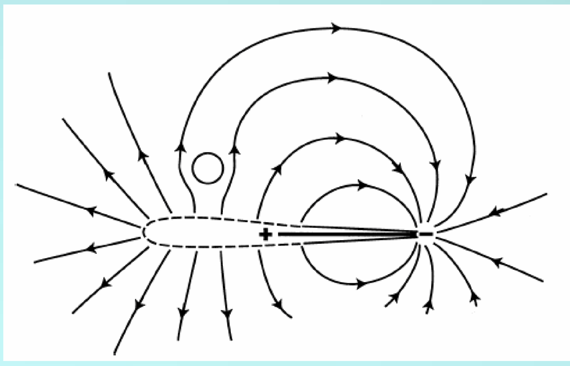
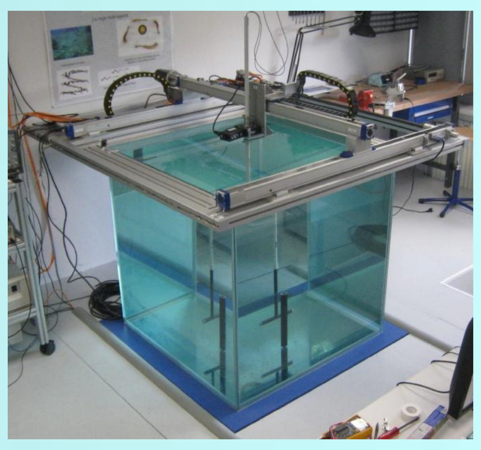
This paper deals with the modelling of the perception by the electric sense. The work has been realized in the context of the European project ANGELS. The goal of the project is to build an eel-like robot equipped with the electric sense and capable to split into several modules for exploration and recognitions purposes. In this paper we present more specifically our model of perception that we built for our sensors. The model is analytical and consists in replacing the real electrodes by calibrated charged spheres. Two approaches for electrolocation based on the model are presented: one uses the model and an observer, the second one is a variation of the model and predicts directly the position of the object.

The principles of electrolocation come from Nature:



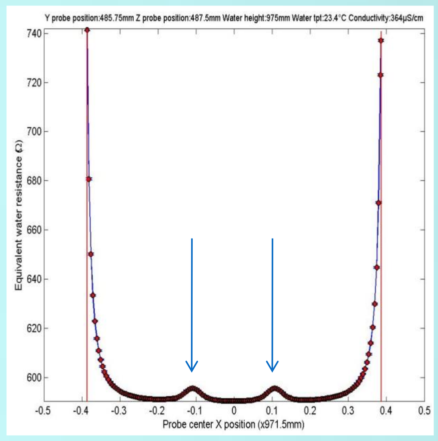
The fish senses the environment by using its electric field. Nearby objects perturbate the electric fields and the currents reentering the skin, so that the fish deduces the existence of the object.

How we re-create artificially the electric sense :



The electrolocation test bed: the sensor is moved thanks to a cartesian robot with a precision of 0.1mm.

The mock up close to the object



By passing close to the object the mock up senses its existence

How we model the perception by the electric sense:

A slender sensor can be modelled by a distribution of calibrated charges spheres (published in ROBIO 2010) : the poly-spherical model (PSM). The current measured is expressed using the simple Ohm's law:

$$I = (C^0 + \delta C)U$$

We measure currents

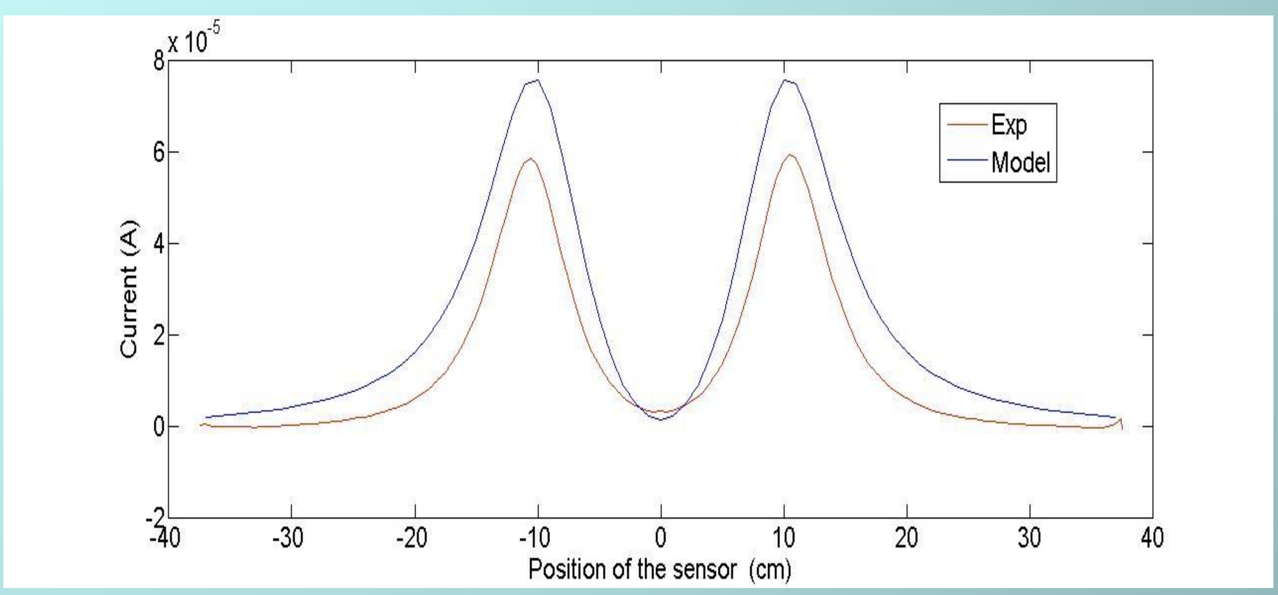
We impose voltages

Conductance for the sensor alone (this term is calibrated to follow the geometry of the sensor)

With objects described by parameters χ

(We have developed expressions applicable for different types of objects)

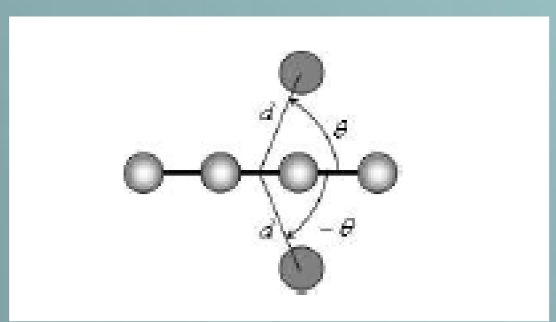
Comparison between the experiment and the model in case of a sensor passing close to a conductive cylinder :



Application to electrolocation:

First approach: use of a simple model with an observer

Using the poly-spherical model (PSM) with an observer it became possible to locate an object:



With the PSM alone the sensor cannot resolve whether the sphere is on the left or on the right.

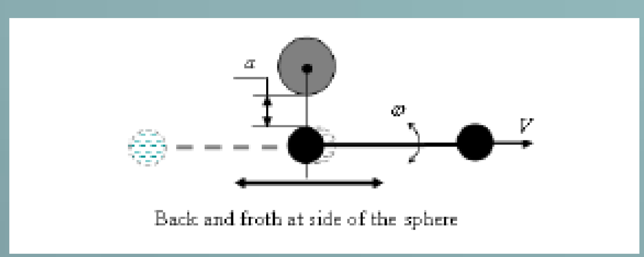
…But the use of a Kalman filter and bio-specific motions make it possible!

The bio-ispired motion	number of electrodes n	error mean of d (%)	error mean of θ(%)	error mean of a (%)
A	n=2	5.90	35.61	6.34
	n=4	3.30	12.56	6.07
B	n=2	2.55	10.11	5.21
	n=4	1.70	8.75	3.47
C	n=2	2.18	12.01	4.67
	n=4	1.24	3.29	2.08
D	n=2	2.12	6.83	3.41
	n=4	1.02	0.82	2.01

TABLE I

SIMULATION RESULTS FOR THE MOTIONS

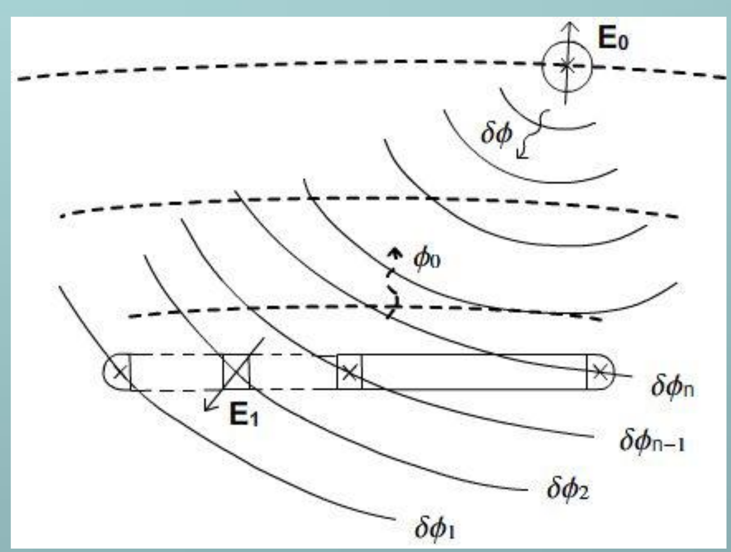
Different movements (A,B,C,D) were compared. The best one was back movement with yawing at the side of the sphere (D).



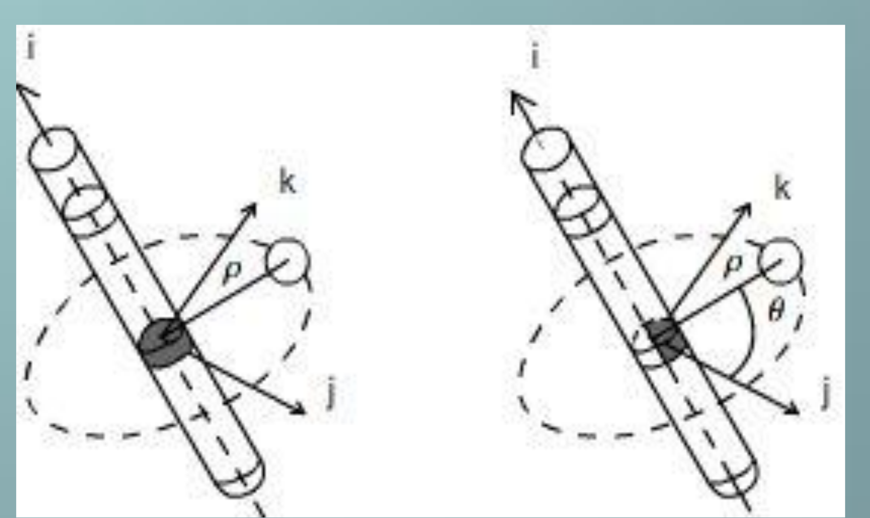
The best strategy was found to be the front and back movement with yawing at the side of the sphere (published in IROS 2010)

Second approach: use of a method to predict the lateral currents

With the method of reflections and the division of each electrode in two lateral sections, it is now possible to locate an object without any additional algorithm (submitted to IEEE T.Robotics)



According to the method of reflections each object reflects an incoming field. Here the sensor emits a field E0 which is reflected by an object. Then the reflected field E1 by the object is re-emitted towards the sensor…



…If each electrode is divided in lateral sections (Right), whereas the PSM was applied to the full electrodes (Left), the pertubation relative to E1 is of opposite sign on the lateral sections. The new model we built can predict this phenomenon, giving the crucial information on the location of the object.