Autonomous Underwater Docking Using Active/Passive Electro-location

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Abstract

In the context of Remotly Operated Vehicule (ROV) for underwater application, connecting the robot to its docking station can be a significant challenge [2]. ROV have to navigate in a complex and unpredictable environment since the perception is limitted. Optical and Acoustic sensor can not be used is this kind of environment because blind spots can occur and short range obstacles may interfere. To perform the docking, it also necessary to provide it a guide. In those situations, with poor visibility, to increase the perception, we have to use an other sense. Electric sense can overcome these limitations and improve the perception of the underwater environment.

Discovered in the 50's ([7]), the electric sense, is the ability to obtain the perception of an environment based on the perturbation of an electric field. Some weakly electric fish, like the *Gnathonemus petersii*, are able to generate an electric field around them to navigate in turbid water, to communicate or to look for hidden food under the sand. They polarize their body relatively to an electric organ discharge that is located just before the tail (figure 1 (a)). Then, they use a large number of electro-receptors along their body to detect a deformation of the electric field and they use a brain process to create a 3-D picture of their environment ([4] and [9]). This capability to create an electric field and sense an object in its surrounding is called active electro-location (figure 1 (b)). Some others aquatic species, have the ability to detect theses electric fields but also electric potentials generated by muscle or nerve. So, through some electro-receptors they are able to detect others animals. This capability to locate electrogenic sources is called passive electro-location. In [6], A. Kalmijn presents this behavior with electro-receptive animals such as sharks (*Scyliorhinus canicula*) and rays (*Raja clavata*) which are able to detect some prey buried under the sand. D. Hopking ([5]) compares this passive electro-location as a passive listening. The electric fish and electro-receptive animals give us a new way of sensing in challenging environments.

Work has been made to investigate on the application of the electric sense for a robotic purpose ([1] and [8]). Because of this sense is omnidirectional, it is particularly appropriate for the obstacle avoidance. But it can also be used for obstacle detection and localization, this behavior is called electro-location. Then, [3] present a new approached of electro-location using a reflex navigation based on passive electro-location in real fish. This technique allows to avoid any electrically contrasted object or to seek a particular contrasted object while it's avoid others. Even if we don't know the position or the orientation of the source of the electric field in the environment, we track the current lines generated by a exogenous electric field to guide the probe. In the following, we propose to use the passive submodality of the electric sense using a reflex navigation [3], to provide an autonmous docking for ROV wich will be also be able to avoid abstacles.

This approch does not need a model of the environnement and it's cheap to implement. It just need to equipe the docking station of an active probe which will generate the electic field.

I. Experimental setup and Control

We want to demonstrate the ability of a ROV equiped with the electric sens to achieve a task of docking in a complexe scene. The experiment has to show how it's possible to guide a ROV in a autonomous way from any initial position to its docking station with or without object in the scene. The docking station is equiped with a two electrode probe which generates an electric field (figure 2 (a)). The ROV used in this experiment is a probe equiped with 6 electrodes. Those electrodes measure the electric field generated by the docking station. The ROV and the docking station are placed in a 1

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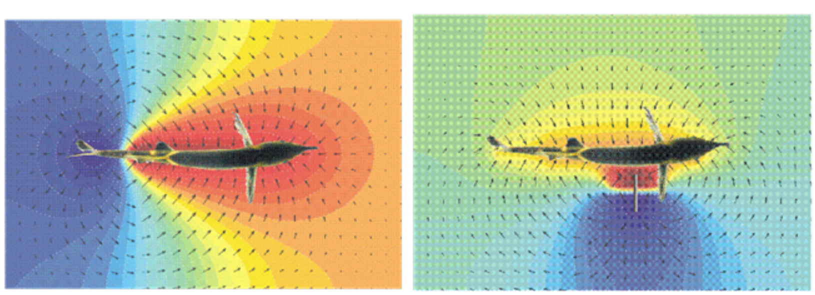
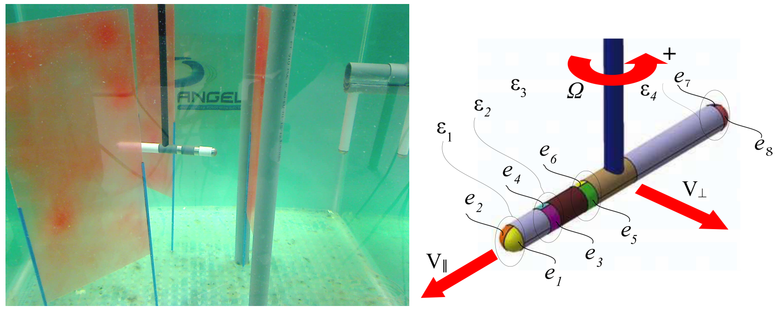


(a) (b)

Fig. 1: (a) Top view of the fish electric field without object (taken from [9]). (b) Top view of the fish electric field with an object (taken from [9]).



(a) (b)

Fig. 2: (a) Experimental setup in a 1 m^3 tank. (b) Position of the electrodes on the probe.

m^3 tank in which are placed three walls (figure 2 (a)). The current measured by an electrode e_k is called I_k. We used for this experiment 4 electrodes (figure 2 (b)) : 2 electrodes located at the head of the probe (e_8 and e_7) and two located at the first ring (e_6 and e_5). The aim of this experimment is that the ROV must reah the docking station from any initial position in the aquarium by following the electric field lines. Because of the physics, the current lines of the electric field must be deformed by non-conductive objects. We want to use that proprerty to avoid ostacles and reach the docking station.

Based on the reflex navigation [3], we control our probe using the passive electro-location to reach the docking station. The locomotion of the probe (figure 2 (b)) is along two movements of translation, an axial linear velocity ($V_{\|}$), a radial linear velocity ($V_{\perp}$), and an angulaire one Ω othogonal to the plane of the scene. The figure 3 (a) shows how the current measured by the probe are combined to achieve the autonomous control with a proportionnal gain. Ratio of currents is used to avoid dependence on the conductivity of the environment (gamma) unlike [2], so we can use this solution in fresh and salt water. With this control algorithm, the probe follows the current lines until it reaches the docking station. If objects are present in the scene, the current lines are deformed and the probe will naturally ovoid them. If the objects are distant by more than one and a half times the length of the probe from the docking station, the probe will be aligned with the docking station.

The figure 3 (b) shows the path of the ROV from an initial position to the docking station. As we can see in this figure, the probe bypasses the wall which blocked it to go to the docking station, reaching its goal. Thus using the electric sens in this case allows to avoid obstacle and create a guide so that a ROV reaches its docking station.

REFERENCES

[1] F. Boyer, P.B. Gossiaux, B. Jawad, V. Lebastard, and M. Porez. Model for a Sensor Inspired by Electric Fish. *IEEE Transactions on Robotics*, 28(2):492–505, April 2012.

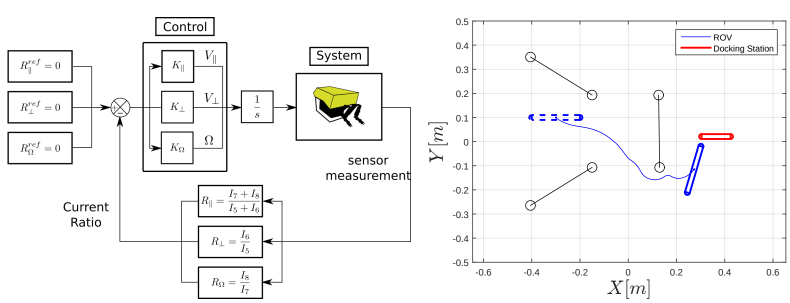
[2] Frederic Boyer, Vincent Lebastard, Christine Chevallereau, Stefano Mintchev, and Cesare Stefanini. Underwater navigation based on passive electric sense: New perspectives for underwater docking. *The International Journal of Robotics Research*, 34(9):1228–1250, 2015.

[3] Frederic Boyer, Vincent Lebastard, Christine Chevallereau, and Noel Servagent. Underwater Reflex Navigation in Confined Environment Based on Electric Sense. *IEEE Transactions on Robotics*, 29(4):945–956, August 2013.

[4] AA Caputi, R Budelli, K Grant, and CC Bell. The electric image in weakly electric fish: physical images of resistive objects in gnathonemus petersii. *Journal of experimental biology*, 201(14):2115–2128, 1998.

[5] Carl D Hopkins. Passive electrolocation and the sensory guidance of oriented behavior. In *Electroreception*, Encyclopedia of Perception, pages 264–289. 2005.

[6] A. J. Kalmijn. The Electric Sense of Sharks and Rays. *Journal of Experimental Biology*, 55(2):371–383, October 1971.



(a) (b)

Fig. 3: (a) Command of the autonomous docking with 3 degree of freedom. (b) Path of the ROV from its initial position to the docking station.

[7] H. W. Lissmann and K. E. Machin. The Mechanism of Object Location in Gymnarchus Niloticus and Similar Fish. *Journal of Experimental Biology*, 35(2):451–486, June 1958.
[8] Yonatan Silverman, James Snyder, Yang Bai, and Malcolm A MacIver. Location and orientation estimation with an electrosense robot. In *Intelligent Robots and Systems (IROS), 2012 IEEE/RSJ International Conference on*, pages 4218–4223. IEEE, 2012.
[9] Gerhard Von Der Emde, Stephan Schwarz, Leonel Gomez, Ruben Budelli, and Kirsty Grant. Electric fish measure distance in the dark. *Nature*, 395(6705):890–894, 1998.