Autonomous Underwater Docking Using Active/Passive Electro-location

Steven Bruce Ferrer¹, Vincent Lebastard² and Frédéric Boyer²

Abstract

In the context of Remotly Operated Vehicle (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 limited. 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 autonomous docking for ROV which will be also be able to avoid obstacles.

This approach 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 electric field.

I. EXPERIMENTAL SETUP AND CONTROL

We want to demonstrate the ability of a ROV equipped 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

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] ).

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²S. B. Ferrer is with the Commissariat à l’Énergie Atomique et aux Énergies Renouvelables (CEA Tech Pays de la Loire), Technocampus, 44340 Bouguenais, France, steven.ferrer@cea.fr
V. Lebastard and F. Boyer are with the IRCCyN Laboratory, Mines de Nantes, 44307 Nantes, France, vincent.lebastard@mines-nantes.fr frederic.boyer@mines-nantes.fr
A $m^3$ 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 experiment is that the ROV must reach 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 property to avoid obstacles 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 ($V_⊥$), and an angular one $Ω$ orthogonal 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 proportional 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 avoid 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 sense in this case allows to avoid obstacle and create a guide so that a ROV reaches its docking station.

REFERENCES

