A Biologically Inspired Neural Controller Based on a Self Organization Direction Mapping Network for UVs on Oceanographic Missions

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Introduction and objectives

A brief Introduction

With continuous advances in control, navigation, artificial intelligence, material science, computer, sensor and communication, autonomous underwater vehicles (AUVs) have become very attractive for various underwater tasks. The autonomy is one of the most critical issues in developing AUVs. The design, development, navigation, and control process of an AUV is a complex and expensive task. Various control architectures have been studied to help increase the autonomy of AUVs [1-5].

Trajectory generation with obstacle avoidance is a fundamentally important issue in robotics. Real-time collision-free trajectory generation becomes more difficult when robots are in a dynamic, unstructured environment. There are a lot of studies on trajectory generation for robots using various approaches problem [2]. Some of the previous models [1-3] use global methods to search the possible paths in the workspace, which normally deal with static environment only and are computationally expensive when the environment is complex.

Several papers [4-7] examine the application of neural network (NN) to the navigation and control of AUVs using a well-known backpropagation algorithm and its variants since it is not possible to accurately express the dynamics of an AUV as linear in the unknown parameters. Unfortunately, the backpropagation-based NN weight tuning is proven to have convergence and stability problems. Further, an offline learning phase, which is quite expensive, is required with the NN controllers [5].

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Introduction and objectives

Objectives

► A kinematic adaptive neuro-controller for trajectory tracking of autonomous underwater vehicles robots is proposed and requires no knowledge of the geometry of the robot or of the quality, number, or configuration of the robot's sensors.

► The neuro-controller that we propose is based in the biological sensory-motor control [8-13].

► The kinematic adaptive neuro-controller is a Self-Organization Direction Mapping Network (SODMN), uses an associative learning to generate transformations between spatial coordinates and motion vectors from propellers' velocities.

► The transformations are learned in an unsupervised training phase, during which the underwater robot moves as a result of randomly selected propellers' velocities.

► The efficacy of the proposed neural controller is tested experimentally by an underwater vehicle capable of operating during large periods of time for observation and monitoring tasks.

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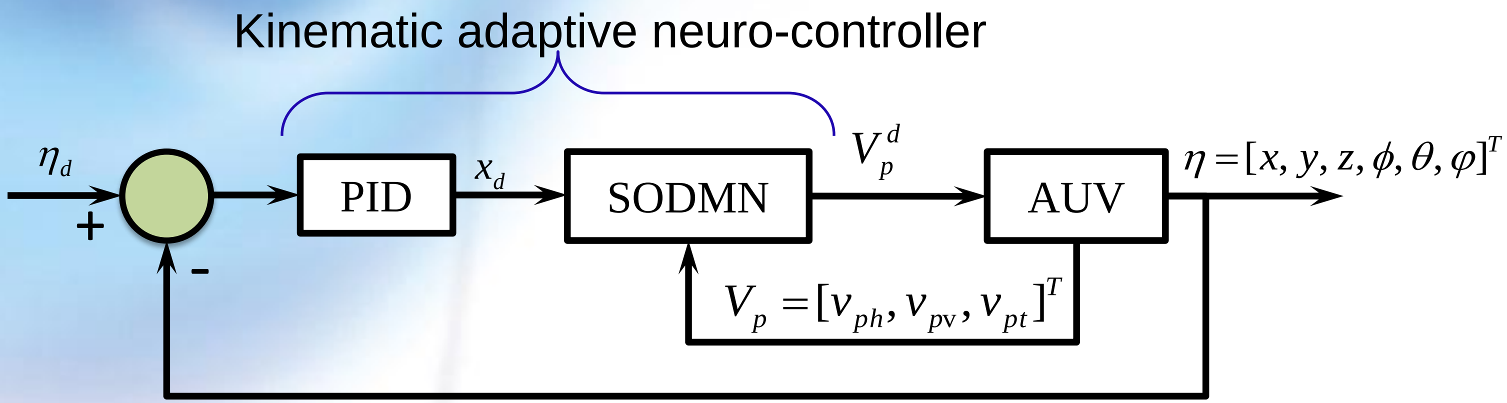
Architecture of the Neural Control System



$$v_{ph} = [v_{phr}, v_{phl}]^T; v_{pv} = [v_{pvr}, v_{pvl}]^T; v_{pt} = [v_{ptr}, v_{ptl}]^T$$

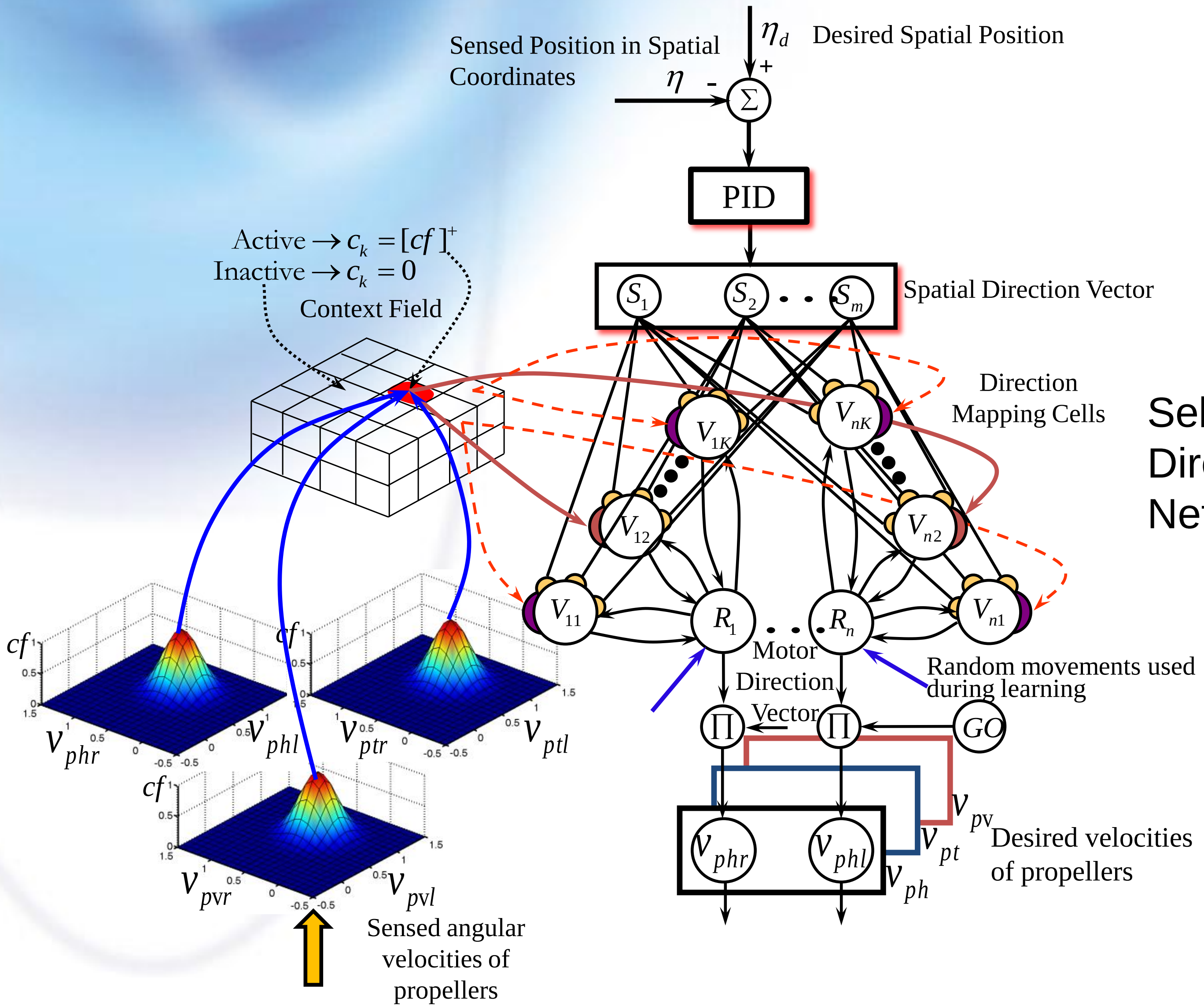
$v =$ velocity; $p =$ propeller;
$h =$ horizontal; $\mathrm{v} =$ vertical;
$t =$ transversal; $r =$ right;
$l =$ left.

$v_{phr} =$ right horizontal propeller velocity.
$v_{phl} =$ left horizontal propeller velocity.

Neural architecture for adaptive navigation of autonomous underwater vehicles

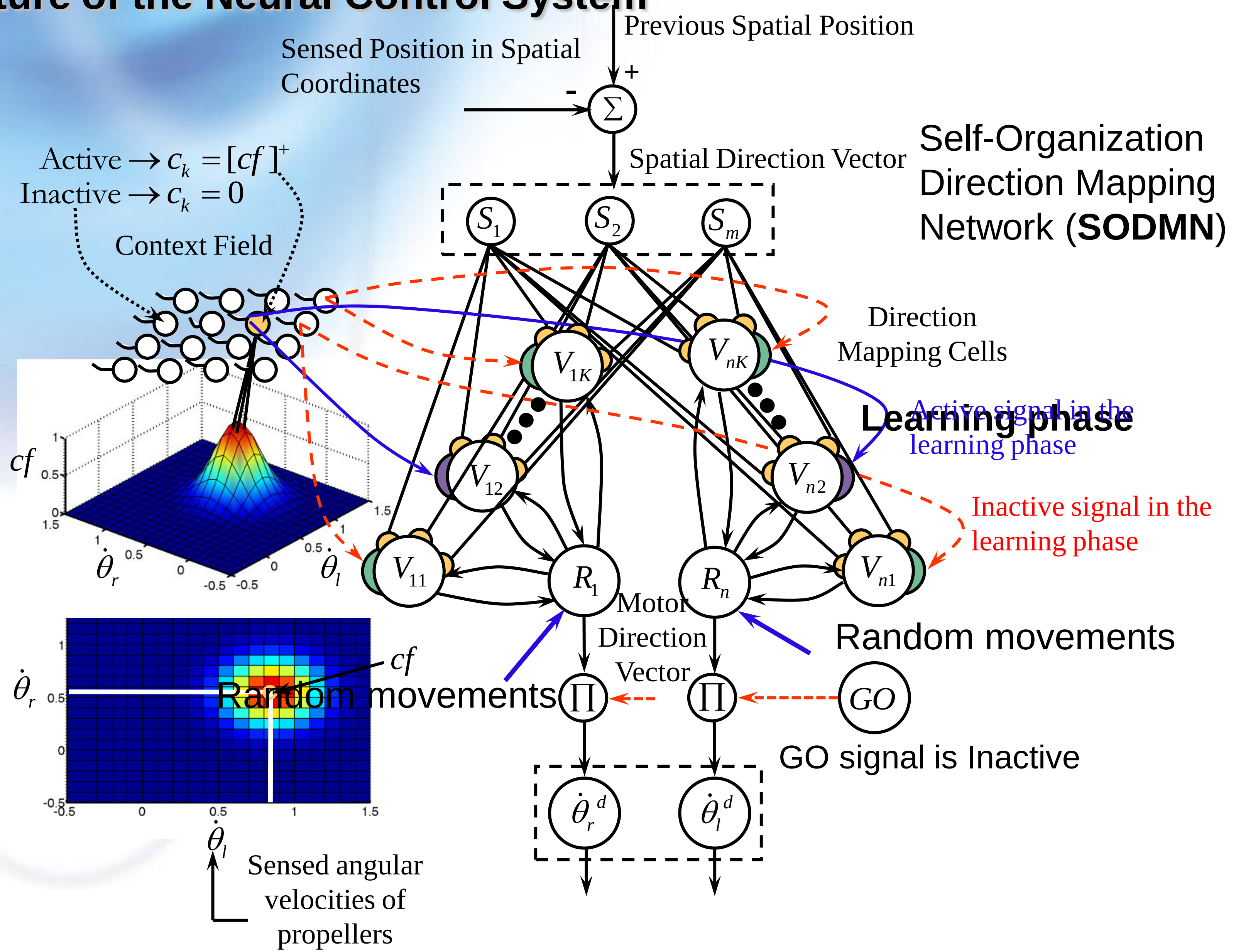
Self-Organization Direction Mapping Network (SODMN)

Architecture of the Neural Control System



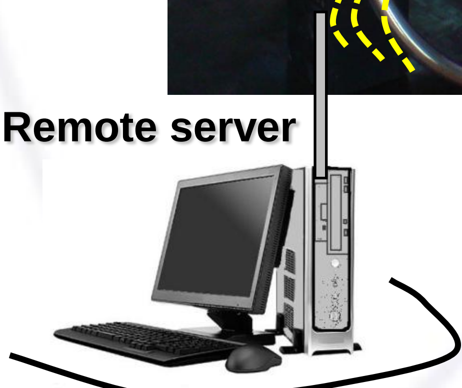
Self-Organization Direction Mapping Network (SODMN)

Architecture of the Neural Control System



Experimental Results

Remote server



Principal characteristics of the AUV-UPCT

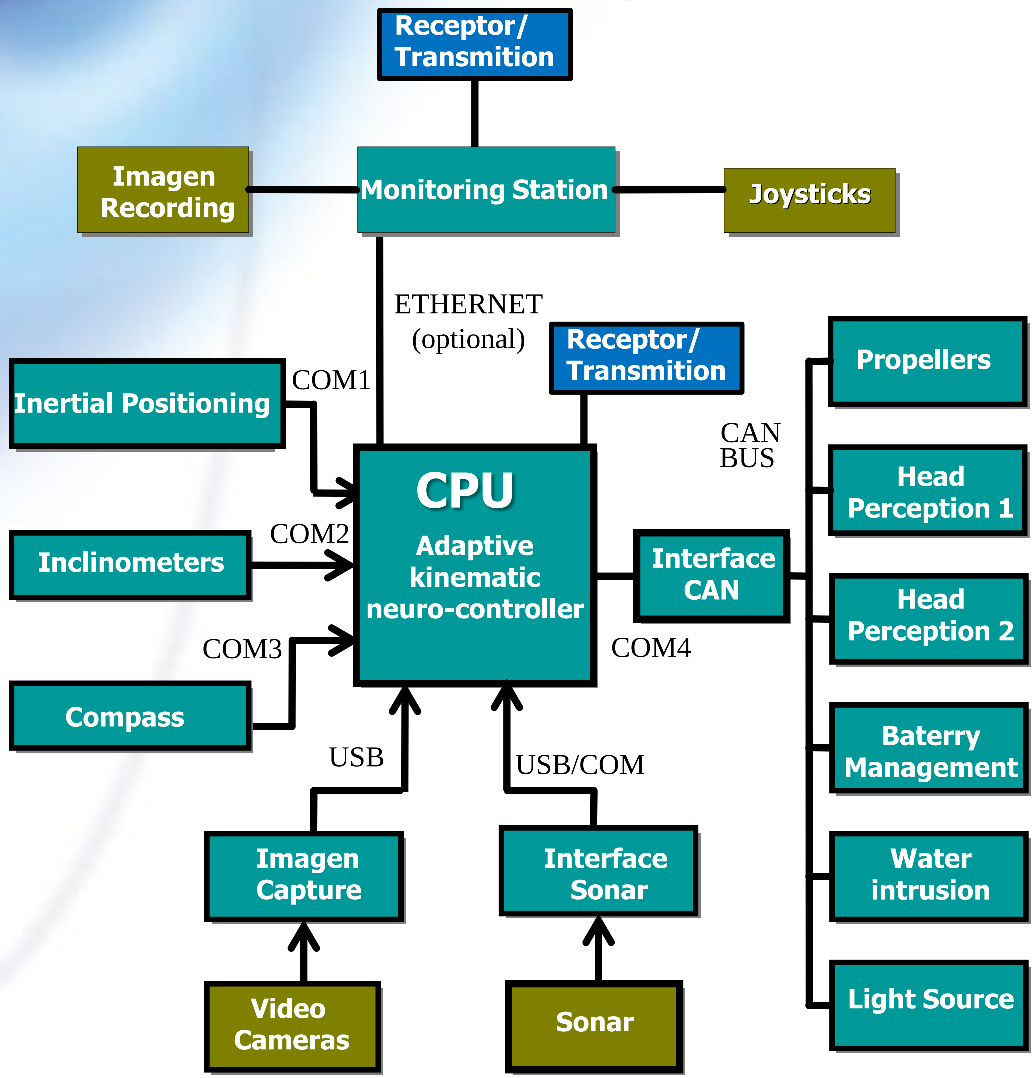
Weight of the Vehicle: 160 Kg.
Dimensions: 1680 x 600 x 600 mm
Max. Speed.: 4 knots (48V), 2 knots (24V).
Operational depth: 300 meters.

Test Data:
- Weight of the Vehicle: 148.4 Kg
- Ballast: 15 Kg.
- Total Weight: 163.4 Kg
- Displacement: 163.8 dm^3
- Ballast Displacement: 1.92 dm^3
- Nett Upthrust: 2.32 Kg

Elements:
- Camera and Halogen Lights
- Side-Scan sonar
- Sub-bottom profiler sonar
- Video Camera
- Inertial system
- Acoustic Modems
- Depth Sensor
- Speed Sensor: Doppler Velocity Log (DVL)
- Acustic doppler current profiler (ADCP)
- Module of the distribution control system
- Submersible Ultraviolet Nitrate Analyzer
- Multiparametric Sonde (YSI-66000 V2-4)
- Power supply unit

Experimental Results

Interconnection of hardware components of the AUV-UPCT



Experimental Results

First Navigation Test of the AUV-UPCT

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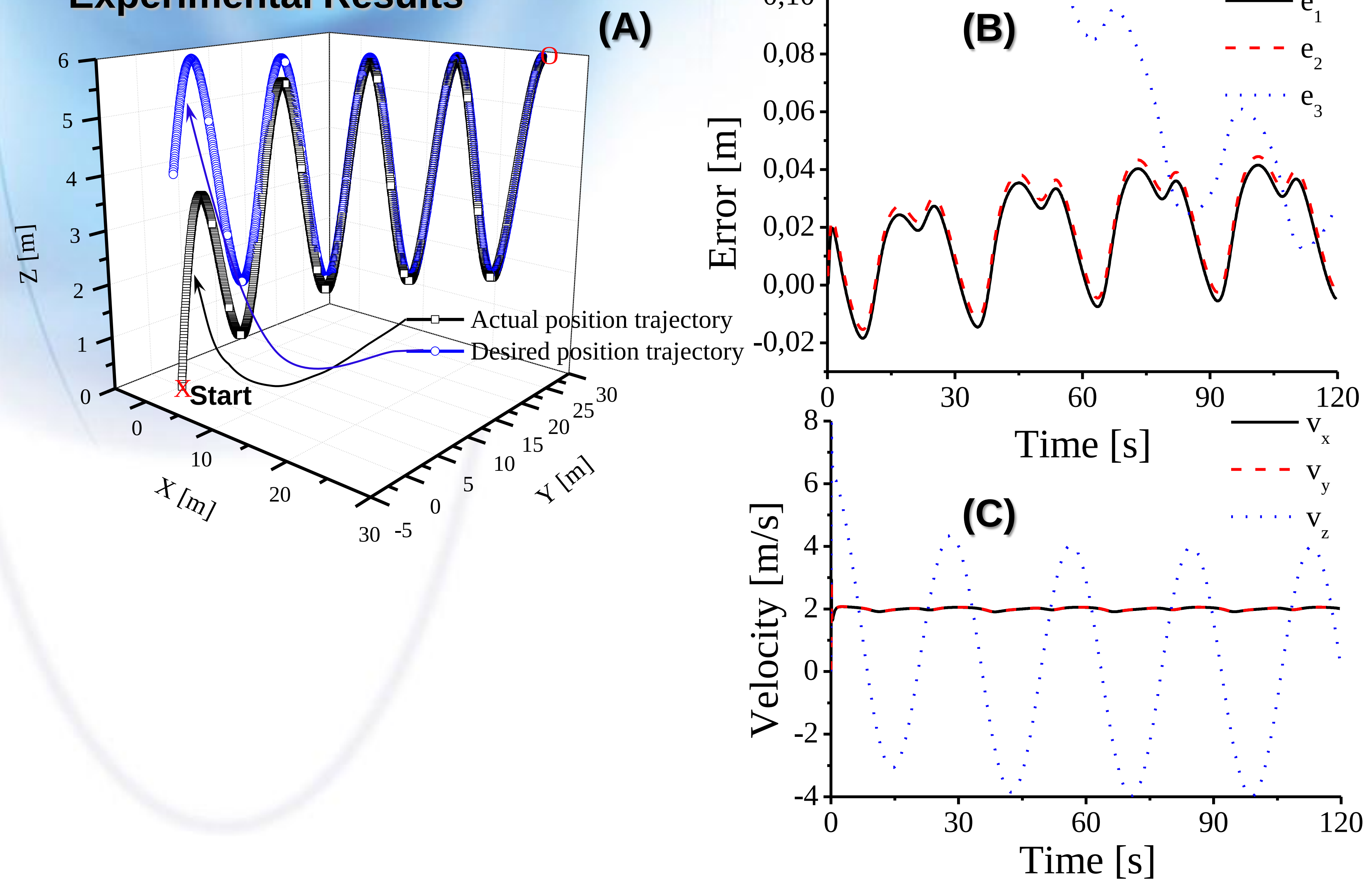
Experimental Results



Conclusions

► In this paper, a biologically inspired neural network for the spatial reaching tracking has been developed.

► This neural network is implemented as a kinematic adaptive neuro-controller.

► The Self-Organization Direction Mapping Network (SODMN) uses a context field for learning the direction mapping between spatial coordinates and motion vectors from propellers' velocities.

► The transformations are learned during an unsupervised training phase, during which the underwater robot moves as result of randomly selected angular velocities of propellers. It has the ability to adapt quickly for unknown states.

► The Self-Organization Direction Mapping Network (SODMN) requires no knowledge of the geometry of the robot or of the quality, number, or configuration of the robot's sensors.

► The efficacy of the proposed neural network for reaching and tracking behaviours was tested experimentally by an underwater robot.

Future and Collaborations

► This biologically inspired neural network for spatial tracking and reaching which has been developed on a propelled AUV is proposed to be tested on a glider to improve knowledge of the underwater followed path in order to get the prototype of a new generation of robot gliders.

► Inertial navigator and processor would decrease the energetic autonomy of the robot glider prototype, but this will provide a test bed for behaviour algorithms implementations. (E.g. Obstacles avoidance, optimal energetic behaviour in underwater currents, CTD buoyancy control, minimal energy path tracking, eddies exit or profiting,...)

► Propose the Underwater Vehicles Laboratory of the Polytechnic University of Cartagena at the Ship Science and Ocean Engineering University School building as Gliderport and as Learning and Training Phase Centre of the new glider prototype.

► Synergies with local and Port authorities, fishers' association and facilities of Cartagena, Spanish Armada and Campus Mare Nostrum are shared to support Med Sea investigations.

► Partnerships from EGO and COST are required in order to participate in GW2 with the project that has been proposed.

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