Available online at www.sciencedirect.com

ScienceDirect

IFAC-PapersOnLine 49-23 (2016) 420–425

CADDY Project, Year 2: The First Validation Trials ⋆

Nikola Mišković * Antonio Pascoal ** Marco Bibuli ***
Massimo Caccia *** Jeffrey A. Neasham **** Andreas Birk †
Murat Egi ‡ Karl Grammer § Alessandro Marroni ‡
Antonio Vasilijević * Zoran Vukić *

* *University of Zagreb Faculty of Electrical Engineering and Computing, Croatia, (e-mail: nikola.miskovic@fer.hr).*
** *Instituto Superior Tecnico, Portugal, (e-mail: antonio@isr.ist.utl.pt)*
*** *Consiglio Nazionale delle Ricerche, Italy, (e-mail: marco.bibuli@ge.issia.cnr.it)*
**** *University of Newcastle, UK, (e-mail: jeff.neasham@newcastle.ac.uk)*
† *Jacobs University, Germany, (e-mail: a.birk@jacobs-university.de)*
‡ *Divers Alert Network Europe, Malta, (e-mail: smegi@daneurope.org)*
§ *University of Vienna, Austria, (e-mail: karl.grammer@univie.ac.at)*

Abstract "CADDY - Cognitive Autonomous Diving Buddy" is an FP7 project that that is devoted to developing a cognitive underwater robotic system that will help divers during their activities in this hazardous environment. The envisioned resulting system will play a threefold role similar to those that a human buddy diver should have: buddy "observer", buddy "slave", and buddy "guide". During the second year of the project, validation trials were organized in Croatia with the purpose of testing all developed algorithms that will enable the three roles of the CADDY system. The trials were structured in five experiments. This paper is devoted to providing a concise overview of the conducted experiments and major results.

Keywords: Autonomous and remotely operated (surface and underwater) marine vessels, Cooperative navigation and control, Guidance, navigation and control (GNC) of unmanned marine vehicles (surface and underwater)

1. INTRODUCTION

The main idea behind FP7 project "CADDY – Cognitive Autonomous Diving Buddy" is to establish an innovative set-up between a diver and companion autonomous robots (underwater and surface) that exhibit cognitive behaviour through learning, interpreting, and adapting to the divers behaviour, physical state, and actions, CADDY (2014). The CADDY project replaces a human buddy diver with an autonomous underwater vehicle and adds a new autonomous surface vehicle to improve monitoring, assistance, and safety of the divers mission, as shown in Fig. 1. The resulting system plays a threefold role similar to those that a human buddy diver should have: i) the buddy "observer" that continuously monitors the diver; ii) the buddy "slave" that is the diver's "extended hand" during underwater operations performing tasks such as "do a mosaic of that area", "take a photo of that" or "illuminate that"; and iii) the buddy "guide" that leads the diver through the underwater environment.

The most important results that were achieved during the first year of the project can be found in Mišković et al.

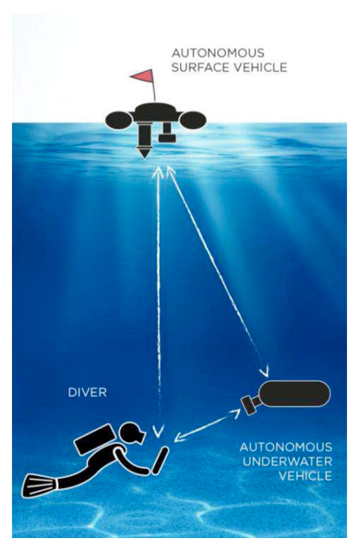

Fig. 1. The CADDY concept.

(2015). During the second year, a major event that took place were the validation trials that were performed in October 2015 in Biograd na Moru, Croatia. The trials were devoted to assessing specific sub-functionalities and subtasks, validating the state of the project progress, trends

⋆ This work is supported by the European Commission under the FP7-ICT project "CADDY - Cognitive Autonomous Diving Buddy" Grant Agreement No. 611373.

2405-8963 © 2016, IFAC (International Federation of Automatic Control) Hosting by Elsevier Ltd. All rights reserved.
Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.10.440

and accomplishments, rectifying the significant issues and providing the guideline for the future work. From functionality point of view, first validation assessment provide evidence that developed system is capable to perform dive buddy "observer", dive buddy "slave", and dive buddy "guide" roles.

This paper is devoted to presenting the main results obtained during these validation trials that were structured in five experiments, as it is described in this paper. The following sections of the paper are devoted to each of the experiment, i.e. Experiment 1: Integration Experiment, Experiment 2: Buddy "slave", Experiment 3: Buddy "guide", Experiment 4: Maximizing system observability by using extremum seeking, and Experiment 5: DiverNet. The description of these experiments is also available in a form of short movies that are available at CADDY (2015a), CADDY (2015b), CADDY (2015c), CADDY (2015d), CADDY (2015e).

2. EXPERIMENT 1: INTEGRATION EXPERIMENT

2.1 Description of experiment

The first experiment is envisioned as an integration experiment where all partners have to integrate their communication schemes, control algorithms, and ensure reliable exchange of data between different segments. The main task of the experiment was to issue a command using CADDIAN language, Chiarella et al. (2015) to perform a mosaic of the area of dimensions m x n from the current point. This command is issued from the surface, and gestures are identified from the surface (see Fig. 2a). The command is then transmitted to the vehicles (Fig. 2b). Two vehicles are involved in the execution of this task (Fig. 2c): 1) underwater vehicle that executes the mosaicing mission by performing a lawn mower pattern close to seabed while collecting data using a stereo camera, and 2) surface vehicle that tracks the underwater vehicle and aids its navigation by transmitting position measurements via acoustic link.

2.2 Results

For the sake of brevity, here we only present major results of each experiment. The video showing the summary of the experiment can be found at CADDY (2015a).

Underwater leader experiment Both the leader and the follower vehicles ran an Extended Kalman Filter (EKF) to independently estimate the positions and velocities of both vehicles in the experiment. The surface vehicle needs to estimate the position of the underwater one to be able to track it; the underwater vehicle needs to estimate the position of the surface one in order to use the USBL measurements (range and bearing between vehicles) to infer its own position. It should also be mentioned that position measurements are obtained only around once every 6 seconds and the surface vehicle has no extra information regarding the motion of the underwater one.

The underwater path-following nominal mission consisted on a lawn-mower pattern with leg distances of 1 meter, 1.5 meters altitude from the seafloor and at nominal speed of 0.3m/s. If a precise following was achieved the acquired horizontal image overlap would be around 50%. The survey area is defined by the diver in real time when initiating the mission (for the data shown in Fig. 3 was 20m by 45m). Since the distance between two consecutive lines was too small some connection paths were included to increase the turning radius to 2.5m. The achieved overall performance was good with maximum errors on the lines beginning reaching 0.5m and with a high convergence rate to the line.

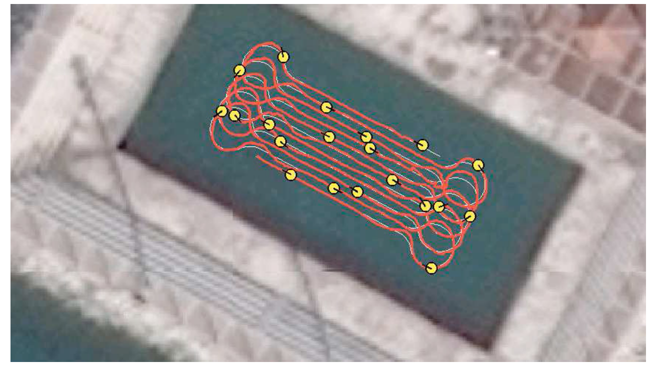

Fig. 3. Lawn-mower pattern mission inside a pool: nominal mission in white; vehicle path in red and vehicles pose the yellow circles.

Motion performance of the MedusaD has been computed and evaluated using the metrics in Saggini et al. (2015). The results show excellent MedusaD underwater path following performance with mean distance to path of 0.09 meters along the line sections and 0.22 meters for turn sections.

Surface tracking The Surface Tracking Controller was designed so that the surface vehicle is in a certain area that improves, among other things, the acoustic communications with the underwater vehicle, and at the same time tries to avoid being on top of it. The choice of this approach, instead of tracking a specific point, was due to the fact that the underwater vehicle can perform any type of mission and therefore the position estimation can be an extremely difficult task. To implement this, an artificial potential field technique was used and the corresponding velocity profile towards the target is shown in Fig. 4. This figure relates the distance between the surface and underwater vehicles and the desired speed for surface vehicle.

Fig. 5 presents the inter-vehicle distance over time. In this figure, the range was used as a ground-truth measurement and the upper and lower limits of the equilibrium zone were calculated based on the parameters used on a specific mission. The overall performance was good with maximum error of 1.2 meters.

Complex gesture recognition on dry land In order to detect complex gestures, 2D information was used to detect and classify the hand gesture; and only 3D information was used to validate the detection of the hands. Specifically, a hierarchical pipeline implemented for classification uses first Haar Cascade classifier to detect possible hands candidates in the 2D image, and then this candidates are filtered out using Multi-Descriptor Random Forests