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The European Marie-Curie Training Network ROBOCADEMY

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Abstract: The Marie Curie Initial Training Network ROBOCADEMY was initiated in 2014. The network unites 10 European research institutes and companies that are leading in the area of underwater robotics. Through the Network, 13 young researchers from 13 European and non-European countries are given the opportunity to obtain a PhD and gain hands-on experience in underwater robotics. Following the spirit of Marie Curie Actions with their strong focus on education and training, a challenging scientific training programme is complemented by intensive on-the-job training and soft skills courses. The scientific objective of ROBOCADEMY is to contribute to the next generation of resilient and robust Autonomous Underwater Vehicles (AUVs). This paper gives a brief introduction and overview of the concept and organization of the ROBOCADEMY ITN, as well as of the scientific research topics addressed.

Keywords: Underwater robotics, academic training, Marie Curie ITN.

1. INTRODUCTION

In 2014, funded by the Marie Curie Programme under FP7, the ROBOCADEMY Initial Training Network (ITN) was established [1]. The objectives of the Network are to enable young researchers from Europe and abroad to develop a skill set that allows them to become experts in underwater robotics.

Figure 1: The ROBOCADEMY team.

This skill set consists of expertise in state-of-the-art methods related to robotics in general, and to underwater robotics in particular, as well as of a number of soft-skills, including hands-on experience with work in interdisciplinary and international project teams, project management, and the presentation of scientific content in papers and on international conferences. Through the close cooperation of European research institutes, universities, as well as large and small industrial companies leading in the fields of robotics and maritime technology, ROBOCADEMY offers first-class training and research opportunities for the 13 young researchers selected from applicants from all over the world (Figure 1).

In well-defined and well-tutored PhD research projects, the ROBOCADEMY fellows work on topics that push the state-of-the-art in the area of robust, reliable and autonomous underwater robots. Specialized scientific training modules enable the fellows to obtain both a sound basis in robotics and an introduction to topics that are specific to their research areas. This is complemented by a high-quality soft-skills training programme and the opportunity to gain practical experience through secondments to the maritime industry and to oceanographic research institutes.

2. THE ORGANIZATION OF ROBOCADEMY

ROBOCADEMY brings together ten of the leading European research institutes and companies in the field of underwater robotics (Figure 2).

Figure 2: ROBOCADEMY Consortium.

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In ROBOCADEMY, the scientific work of each "Early Stage Researcher (ESR)" or "ROBOCADEMY fellow" is supervised by two professors. In most cases, these come from the academic members of the project. Each fellow has his or her own Career Development Plan. This plan is developed in cooperation with the main supervisor and updated each year.

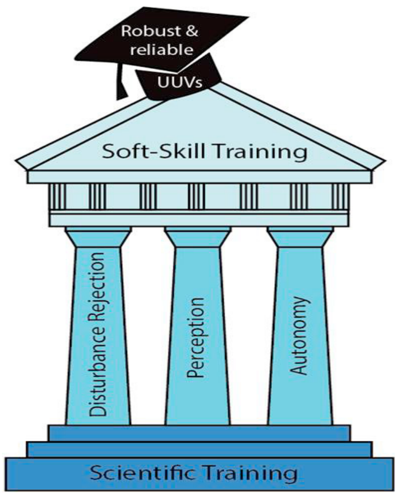

Figure 3: The ROBOCADEMY architecture.

The general progress of the scientific work and personal development of the ROBOCADEMY fellows is monitored by the Progression Board. This comprises all PhD supervisors in ROBOCADEMY and is responsible for the development of a Strategic Research Agenda for the project, to decide on modifications of the SRA and the individual PhD topics, if needed, and to mitigate problems, should they arise.

3. ROBOCADEMY SCIENTIFIC CONCEPT

On a solid basis of scientific training and roofed by complementary soft-skills training, the central part of the ROBOCADEMY architecture are the scientific research projects (Figure 3). These target key technologies needed for the robust long-term deployment of autonomous underwater vehicles (AUVs). The research questions that have to be addressed in this context were grouped in three topics, called "Action Lines" in ROBOCADEMY: AL1 - Disturbance Rejection, AL2 – Perception, AL3 – Autonomy. In the following, we will briefly present two typical ROBOCADEMY research projects, one in the Action Line Disturbance Rejection and the other in the Action Line Autonomy.

3.1 RESEARCH IN DISTURBANCE REJECTION

In this action line, methods to overcome the disturbance effects typical for natural underwater environments are developed. Such disturbance effects may be caused by currents, water turbidity, temperature gradients, and other properties of the natural underwater environment. They can corrupt the operation of a robot, disturbing robot locomotion control, robot navigation, sensory perception and other core capabilities of robotic underwater systems, as well as causing excessive corrosion and deterioration of technical components. In ROBOCADEMY, the focus of research is on methods that help to reduce the effects of external disturbances on the robot locomotion control.

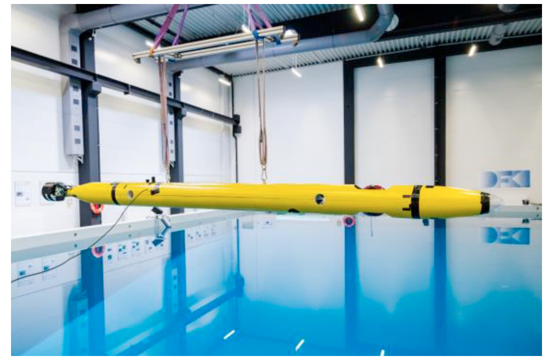

Figure 4 DFKI AUV Leng [4].

Figure 5: DFKI AUV Dagon [5].

Several of the ROBOCADEMY fellows work on the topic of disturbance rejection. An interesting approach is taken by one of the ROBOCADEMY researchers working at the Robotics Innovation Center (RIC) of the German Research Center for Artificial Intelligence (DFKI) in Bremen. His approach is to use machine learning to improve and optimize the motion models needed for a reliable robot navigation under dynamic natural environment conditions.

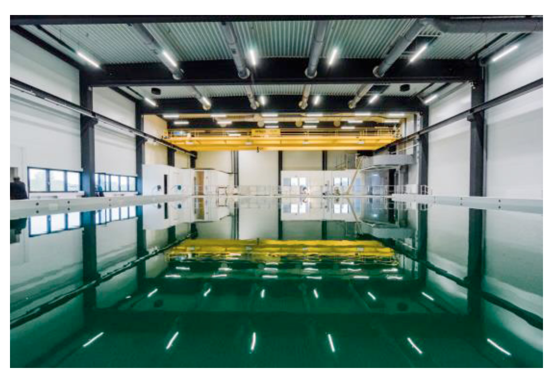

Figure 6: DFKI RIC Maritime Exploration Facility.

The approach foresees the development of an intelligent framework to monitor and analyse the interaction of an autonomous underwater vehicle on a long-term mission with the dynamic changes in its natural environment. The framework gathers data from the on-board navigation sensors of the AUV and, by analysing them, creates a knowledge-base of behaviour patterns that are typical for the AUV. When discrepancies between the actual and the predicted behaviour are detected, a learning process is triggered which updates online the internal motion models that the robot uses to execute certain tasks.

Through ROBOCADEMY, the young scientists have access to on-going projects and systems at the host locations. At DFKI, the algorithms can be tested on several state-of-the-art vehicles, among them the LENG [4], DAGON [5] and FLATFISH [6] AUVs (Figure 4 and Figure 5). As testing environment, the DFKI RIC Maritime Exploration Facility (Figure 6) can be used.

In a first step, supervised learning methods including artificial neural networks (ANN), support vector machines (SVM), kernel ridge regression (KRR), and Gaussian processes (GP) where applied for learning the models of AUVs LENG and FLATFISH. The data used were data from on-board navigation sensors including Doppler velocity logs (DVL) and inertial measurement units (IMU).

To select the most appropriate method for this task, the performance of the robots was comparatively evaluated using three different metrics. (1) The mean squared error (MSE) which is a measure of the squared error-loss between the measured and predicted samples. (2) The coefficient of determination (R^2) which is a measure of how good the model expects future predictions to be. (3) The learning time needed to train the model with a selected number of samples.

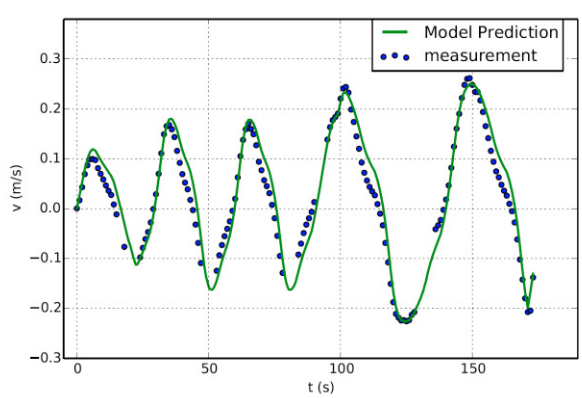

Figure 7 Predicted and DVL measured velocities.

For ensuring the best performance of the regressors, their hyper-parameters were optimized through a cross-validation grid search algorithm using the open source machine learning tool pySPACE [8]. Preliminary results show that GP method produced very accurate results. However, it is also the most computationally demanding method because several hyper parameters need to be optimized. KRR shows a low error as well, but also uses the whole set of training samples to make a new prediction, with the required memory increasing significantly as the number of samples grows. For the ANN, the performance depends on the architecture of the perceptron. Adding more layers improves the accuracy, but can sometimes result in over-fitting or learning the noise in the system. SVMs show very good accuracy as well as computational efficiency (Figure 7). They don't rely on the full set of training samples to produce a new prediction, but only on specific samples called the support sample or vectors.

Using a DVL data set of 9622 samples, results are reported in Table 1.

Table 1. Page margins

Method	MSE	R^2	Training time (sec)
GP	0.000137	0.9699	37.05
SVR	0.000073	0.9838	2.74
ANN	0.000269	0.9407	1.93
KRR	0.000203	0.9553	1.44

3.2 RESEARCH IN AUTONOMY

Robots that are designed to operate on their own and unsupervised for hours, days or even weeks in the oceans or under ice must have a high degree of cognition and decisional autonomy [3, 4]. One of the ROBOCADEMY research action lines is therefore focused on improving the ability of the robot for perception and decisional autonomy. Perception here means both monitoring and understanding the environment, as well as monitoring and detecting changes in the internal state of the robotic system, which may be subject to degradation over long periods of operation.

The latter is the focus of the research of a second ROBOCADEMY fellow at DFKI RIC. His approach assumes that autonomous Fault Detection, Identification and Recovery (FDIR) is a crucial system ability when it comes to long-term deployment in extreme environments. In applications where even minor system failures can compromise the whole mission, the need of monitoring the integrity of the vehicle and the capability of auto-recovery in case of failure is evident. This is especially critical for subsea-resident hardware which is exposed for extended time periods to hash underwater conditions involving high water pressures, extreme corrosion and biofouling [6].

The approach uses a self-learning fault diagnosis system to monitor the performance, and the degradation of performance, of selected, highly exposed and/or vulnerable system components. When faulty hardware and/or software is detected, the robot is able to self-adapt its internal configuration and thus cope with erroneous system states. The method uses online adaptive data-driven techniques based on model-driven predictive anomaly detection.

In a first step, the thrusters of the robot were used as the critical component to monitor. Performance data and models of the thrusters were used to evaluate and compare of several learning techniques. Accurate thruster models are necessary to improve underwater navigation. Since the propellers face constant tear and wear that alters their hydrodynamic properties, these models have to change over time. Data collected from experiments with the DAGON AUV were used to evaluate several model-learning techniques. They all had in common that no prior knowledge of thruster dynamics was required. For each thruster, rotational speed and electric current consumption were used as parameters for fault detection in an approach similar to that presented in [7]. In the results of the experiment, saturation and asymmetry of the curves are noticeable and affect the prediction performance of the models. Figure 8 shows the regression models with the tolerance thresholds for outliers/faulty measurements. Figure 9 illustrates the occurrence of a fault in temporal data, in which an outlier is noticed by the spike on the residuals signal.

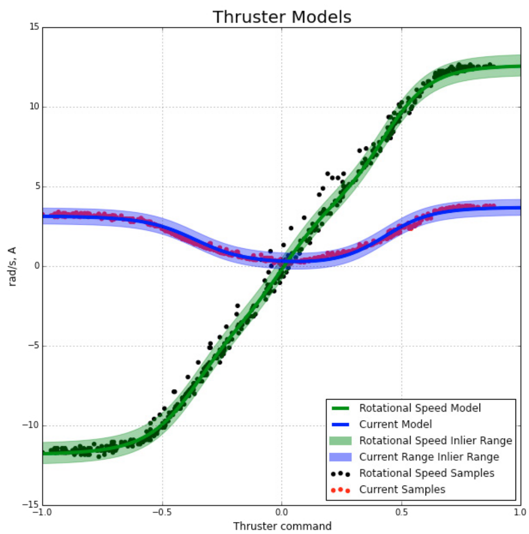

Figure 8: Thruster models used for fault detection.

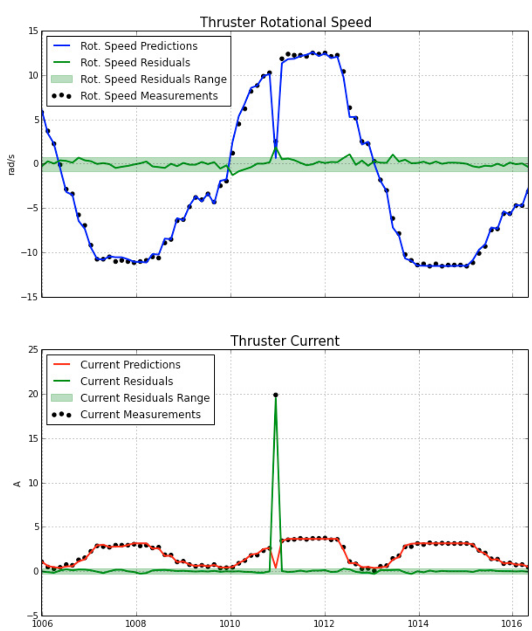

Figure 9: Occurrence of a signal outlier detected by the implemented novelty detection method.

5. CONCLUSION

ROBOCADEMY is an ongoing project funded by the European Commission through the Marie Curie programme in the seventh Framework Programme (FP7). The objective of ROBOCADEMY is to establish an Initial Training Network (ITN) in the area of underwater robotics. As of today, the Network gives 13 young researchers from Europe and other parts of the world the opportunity to become experts in underwater robotics. Employed through ROBOCADEMY by 10 of the leading research institutes and companies in the area of underwater robotics, these so-called "Early Stage Researchers" (ESRs), or fellows, undergo challenging, but very interesting and stimulating training that consists mainly of scientific work, but also of training in non-scientific yet equally important soft-skills. As of today, most of the ROBOCADEMY fellows have completed the first of their three-year training programme. They are well into their respective research projects, from which first results are emerging. The ROBOCADEMY research programme addresses the general topic of long-term autonomy of unmanned underwater vehicles, with three action lines focussing on the topics of disturbance rejection, perception, and autonomy. This paper provides a brief overview of the ROBOCADEMY scientific programme and provides selected examples for concepts and approaches followed in the research action lines.

ACKNOWLEDGEMENTS

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