EXCELLABUST
EXCELLING LABUST IN MARINE ROBOTICS

Staff exchange 2
Research plan

May – June 2016

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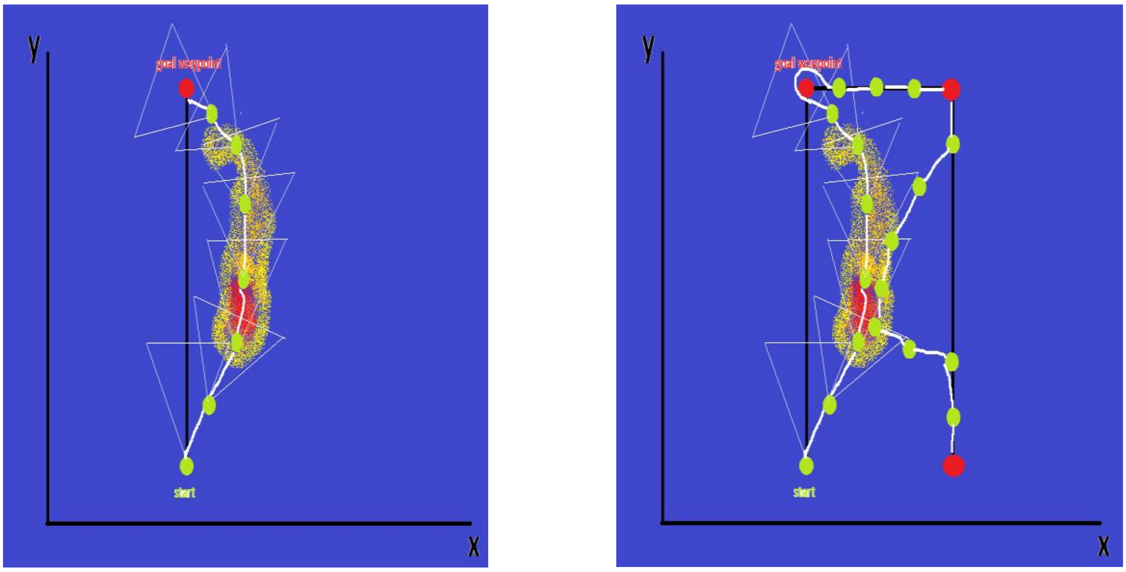
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691980.

1. Experiment description

Sea floor is explored for many reasons, i.e. biological research (search for the sea weed Poseidonia, exploring the biotope and biocoenosis of the coral reefs etc.), archaeological research (sunken ships and ancient settlements on the bottom of the sea), marine safety (sea mines), and many others. Renting a research boat and hiring divers to explore some sites of interest costs a lot of money, and takes a lot of time and beside that divers can explore a relatively small area in search of some interesting sites whose location is unknown.

Another way to explore sea floor is to deploy an AUV (autonomous underwater vehicle) by an UAV (unmanned aerial vehicle), and let the AUV scan the sea bottom in search of some interesting sites. This is possible if AUV behaves in some way similar to the divers. This means that at the beginning of the exploration mission it scans the sea floor in a regular lawnmower pattern, but diverges from it when it spots something interesting to scan in more detail. The graphical representation of this behaviour is given in Fig. 1.



(a) Behaviour of the vehicle while following only one line

(b)) Behaviour of the vehicle while following the lawnmower pattern

Fig 1. Graphical representation of the behaviour of the vehicle. Red points represent the waypoints of the given lawnmower pattern. Green points represent the position of the vehicle in some discrete time moments. The ridge (yellow and red beside the left lawnmower leg) represents some measure of informational gain which the vehicle “collects”.

The goal of this staff exchange is to solve the first part of the above mentioned problem, which is to implement the control of the vehicle (which in general can be an AUV, ASV, or ROV) such that the vehicle follows the line defined by waypoints.

2. Proposed methodology

The methodology which will be implemented is Model Predictive Control (MPC) for the line following manoeuvre. There are many advantages of using this control method, some of which are:

- MPC is a model-based control method, which predicts the behaviour of the system based on its model.
- It solves a repeated Optimal Control Problem (OCP) on a finite time horizon.
- It optimizes the control in the present, taking into account the behaviour of the system in the future.
- Explicitly takes into account all constraints on the controls and states.

One of its main drawbacks is the complexity of the algorithms which solve this optimization problem for nonlinear system with (non)linear state and control constraints. This OCP is not convex so there is no theoretical proof of convergence of the optimization algorithms.

The goal of this research is to use a linear system model with linear state and control constraints, so that the solvers for OCP get less complex. There are some preliminary simulation results in PSOPT toolbox, but its execution time is too slow. The idea is to try using ACADO toolbox for MPC framework, and if it is still too slow, the OCP would be converted into quadratic programming (QP) problem, and solved using the existing optimization libraries. The main advantage of using QP is that is guarantees to find an optimal solution w.r.t. the linear time-invariant system model, and the given linear constraints.

3. Expected outcomes

1. Familiarize with partners from the area of research.
2. Implement the proposed MPC framework for the line following manoeuvre without the external disturbance (which can be sideways flowing sea current) using ACADO toolbox. Test if this implementation is fast enough in the simulation environment..
3. If the implementation in ACADO is too slow (much longer than the sampling period), convert the finite horizon OCP problem into QP and use it to optimize controls.
4. Add the disturbance rejection into the existing MPC framework and test the performances in the simulation environment.
5. Write a report on staff exchange.

4. Further work

1. Conduct experiments with the real system in Biograd na Moru during the Breaking the Surface workshop in October 2016.
2. Publish a conference paper presenting the collected simulation and experimental results.