Motion planning of a fixed wings Uav through an hybrid approach based on artificial potential fields and RRT.

Edoardo Ghini

ghiniedoardo@gmail.com

Gianluca Cerilli

gianlucer@gmail.com

Dipartimento di Ingegneria dell'Universita di Roma La Sapienza

May 23, 2018

I. Introduction

This paper presents a work made for an international challenge[1] that every year involves several academic teams.
The following structure has been respected:
in section II, the problem statement is presented; section III describes technical informations on the hardware and finally in section IV, the adopted solution will be discussed.

II. Problem Statement

All the teams joining the challenge have to compete in several tasks concerning actual problems about the governance of an Unmanned Aerial Vehicle.
Each team brings its prototype of UAV on a common flight ground and tries to score the greatest number of points among all the tasks proposed, which are:

1. Autonomous Flight
2. Obstacle Avoidance
3. Object Detection
4. Object Classification
5. Object Localization
6. Air Delivery

This will be the first partecipation at a competition of this kind for the La Sapienza team, indeed the previous challenges in which the University has already been involved required a human controlled guidance system. Therefore, the autonomous flight issue has to be faced without previous insights on the matter.

[1]The challenge is the AUVSI-SUAS hosted in united states in summer 2018.

i. Starting Point

The aeronautical research department, in the past decade, has spent a big effort working on an autonomous guidance system, that has been designed and implemented by Master students in their thesis.
This system allows to control the complex aerodynamics of the vehicle from an higher level of abstraction. Mainly, it uses a series of waypoints that describes a trajectory.

In this way the aircraft will likely follow a path made of lines that intersects subsequent waypoints.
The system is designed to work on an on-board computer and to communicate with a ground station that continuously sends to and receive from the judges' server, telemetrical data and mission objectives.
A fixed-wings radio controlled aircraft model[2] has been chosen, like those commonly used in hobby modeling, as shown in Figure. 1

Figure 1: *YAK scaled aero model*

ii. Main task

This paper describes the work concerning the area of **automation** and **robotics** of an atomic part of the full Sapienza Flight team, which counts several members coming from an aeronutical background.
So, the autonomous guidance problem that comprehends also the obstacle avoidance clause, has been engaged.
The competition is organized such that, during the various missions of the challenge, each team receives pose informations about fixed and mobile **virtual** obstacles.
Then, the judges check the success or failure in avoiding obstacles according to the **telemetry** data that they receive from each team.
So, there the main goal was to design a **path planning** algorithm that could bring the UAV from a start to a goal position without collisions.

III. Hardware components

i. Propulsion

The engine chosen is a **DLE55** (in Figure 2) :

1. 50 cc monocylinder petrol engine
2. reservoir capable of containing 950cc of petrol
3. equipped with a 7, 4V LiPo battery

Figure 2: *DLE55 motor*

ii. On board computing

The autonomous guidance architecture, implemented in Matlab and Simulink, is converted in compiled high speed

[2]It is a scaled reproduction (1:3 ratio) of the YAK 112

iii

C, Cpp language. It is run by Arduino Due and there is also a Raspberry pi Model 3 that runs a kalman filter in order to process all signals from sensors.

iii. Sensing instruments

iv. Communication devices

v. Auto pilot framework

IV. Hybrid planner

Two different strategies have been merged, since both present different shortcomings and advantages.

i. RRT

RRT (Rapidly-exploring Random Tree) is a probabilistic planner that randomly builds a space-building tree.
It has been used offline considering some motion primitives (produced by some specific velocity inputs) to define a path for the UAV, biasing it towards the unexplored areas closest to the goal.

ii. Artificial potentials

Artificial Potential Fields (APF) have been considered for two main reasons:

- the world can be approximated to a "world of spheres" (since there are cylindrical obstacles that we consider in 2D), that prevents the UAV entering the basin of attraction of some local minima
- when the UAV faces an obstacle, RRT must expand many branches before getting around it. This leads to a significant slowdown

Using APF the UAV can react as soon as entering the range of influence of the obstacle, with a smooth movement. This also because an implementation with vertex fields has been made, replacing repulsive actions with actions forcing the robot to get around it.

iii. Implementation

We consider the kinematic model of a fixed-wing UAV flying at a constant altitude. So, we can neglect the pitch angle, obtaining:

$$\begin{array}{rcl} \dot{x} & = & vcos\psi \\ \dot{y} & = & vsin\psi \\ \dot{\psi} & = & -\frac{g}{v}tan\phi \\ \dot{\phi} & = & u_\phi \end{array} \tag{1}$$

in which the speed v and roll rate u_ϕ are the control inputs.

As described above, for the path planning we use a mixed approach between RRT and Artificial Potential Fields methods.
At the beginning, a random value is generated. If this value is greater or less than a factor (that is decremented after each cycle), the RRT generates respectively a position biased to the goal or a random one, depending from the five primitives of the UAV and it expands a node that represents

the closest possible position of the UAV to the new confguration. If this new position collides with an obstacle, the node is not added to the tree and becomes unavailble for next nodes generation (in a similar way, if all the children of a parent collide with some obstacle, both the children and the parent become unavailable). These five primitives are generated and ordered according to another factor obtained from the APF method. Particularly, depending from the configuration of the UAV and from the range of influence of the obstacles, the total vortex field acting on the UAV is computed.

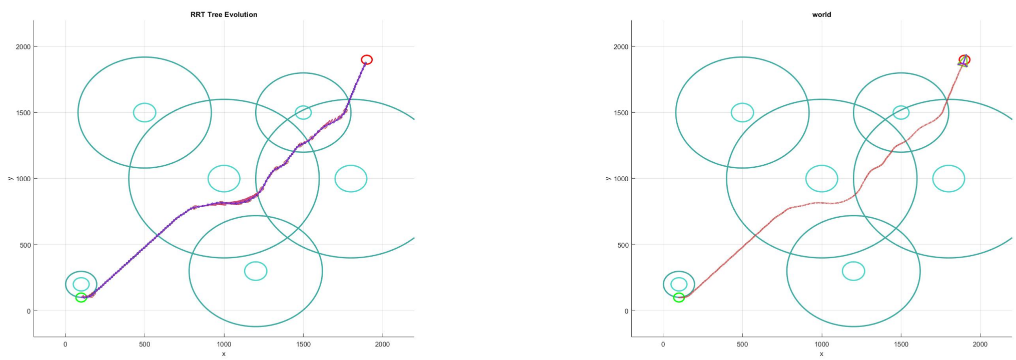

Figure 3: *First image: Positions generated with vortex fields in red; Second image: Final path*

Since the resultant vector of the vortex fields is directed toward the goal, we compute the direction of each primitive and select the one that forms the smallest angles with the direction of the vortex. Thanks to the vortex fields the UAV get around the obstacles avoiding local minima and proceeds faster the goal.

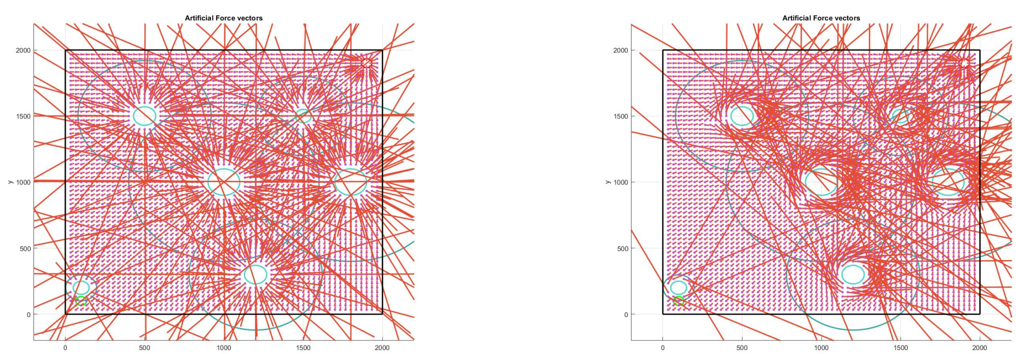

Figure 4: *First image: Repulsive fields; Second image: Vortex fields (tangent)*

V. Conclusion

$$e = mc^2 \tag{2}$$

References

[Figueredo and Wolf, 2009] Figueredo, A. J. and Wolf, P. S. A. (2009). Assortative pairing and life history strategy - a cross-cultural study. *Human Nature*, 20:317–330.

vi