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Development of an Autonomous UAV Managed by Virtual Reality

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The purpose of this work is to develop an autonomous Unmanned Aerial Vehicle (UAV) as a platform for several types of applications, including inspection, monitoring. The first project presented in this paper concerns an autonomous UAV used in conjunction of Virtual Reality to monitor crop fields to ensure a healthy growing process. We used the AR.Drone, a widely commercialized UAV, initially designed for video gaming and customized it to suit the project's requirements. The resulting prototype is the AGUL, equipped with a GPS and a compass for localization as well as other sensors for real-time monitoring of crops (temperature sensor, humidity sensor, high vision camera). The first tests performed indoor showed promising results regarding the autonomous capability of this drone. The next step will be to perform outdoor tests to assess the robustness of the drone to perturbations like wind or GPS localization errors.

Key Words : Autonomous UAV, Virtual Reality, Monitoring, Teleoperation

1. Introduction

For years Unmanned Aerial Vehicles (UAV) have been used in a wide range of civil and military applications, including aerial photography/video, communication relays, and surveillance(1) (pipelines, nuclear facilities, law enforcement…). According to the United States congressional Research Service, about one of three military aircrafts in United States are drones(2) and are expected to expend in the future. One of the obvious benefits to use an UAV is to scout areas which are potentially harmful or difficult of access in order to retrieve data samples or evaluate the possible risks or threats before any human presence is allowed on-site. More recently UAV's nature has shifted to execute more active missions. One of the most famous one is the Predator drone(3) used by the US army for reconnaissance missions but also combat. Although the civil UAV market in 2000 was representing only 3% of the total market revenue(4), this market keeps growing at an increasing speed(5), with the costs beginning to be affordable and the apparition of new needs such as aerial photography for real estate advertising.

Despite their sophisticated design and extensive sensing capabilities, UAVs are usually manually controlled remotely by an operator by using a radio controller. This type of control usually requires training and practice in order to operate the UAV in a safe and accurate manner.

Our approach is to develop or customize existing miniature UAV platforms (maximum takeoff weight less than 30kg, maximum altitude of 150~300m) and integrate Virtual Reality to simplify the drone management. The expected output is a system assisting the path planning and task scheduling processes, managing the autonomous control and real time monitoring of the drone location, status, real time video feed…). The user will only be required to specify high level "missions" (path of the drone, location where to collect data/pictures/videos…). The final goal is to allow any user unfamiliar with UAV to safely operate a drone for a predefined purpose, in a natural and user friendly manner. In this paper we present our first developments of an autonomous UAV used in agriculture for monitoring crops and its link to UC-win/Road, a multi purpose Virtual Reality software. At the current stage of development we use Virtual Reality tools mainly for visualization and to plan

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scheduled tasks.

After introducing the UAV platform used for this project, we will present the prototype developed for agriculture purposes and the link to the Virtual Reality software. In the last part we will present the autonomous control principles and the experimental testing, before concluding with the future works.

2. Autonomous UAV

2・1 The AR.Drone

In 2010 Parrot released the AR.Drone (Fig.1.a, 1.b), a new concept of video game which originality comes from using an actual micro quadrotor UAV (4 propellers), instead of a flight simulator alike as most traditional flight videogames do.

Fig. 1.a: Original AR.Drone with indoor hull

Fig.1.b: AR.Drone with an outdoor hull

That video game was initially developed to run on the iPhone platform which allows the user to connect wirelessly to the drone by an ad-hoc connection and control the drone in a simple and natural way, by tilting the iPhone body, as it is equipped of a 3 axis accelerometer and two gyrometers. Instead of having a view of a flight simulator alike, the player has a real-time video feed of one of the two cameras (front camera and vertical camera). The colors of the hull can be personalized to identify each player so the drone can detect the drone of other players, and virtually chase and “shoot” them to gain points.

The particularity of the AR.Drone is that semi autonomous behaviors are integrated in the default version. For instance, the auto balancing, hovering or take off and landing are performed internally by using a 3-axis accelerometer, a 2-axis gyrometer and a single-axis yaw precision gyrometer. The altitude is estimated from an ultrasonic range sensor mounted vertically. When the drone doesn’t receive any command from the user or in case of Wi-Fi connection loss, the drone enters automatically in hovering mode during a certain period of time, before landing. In that mode, the drone tries to keep it position steady while balancing itself even in case of perturbations.

2・2 AGUL prototype

One of the applications of UAVs is the monitoring and surveillance of a specific area. To answer a customer request, we developed the AGUL prototype (Fig.2.a, 2.b), an UAV to monitor and check the growth of crops in an autonomous way.

Fig.2.a: AGUL drone

Fig. 2.b: AGUL drone, bottom view

The principle is to have a drone that takes aerial views at low altitude, as well as data measures (temperature, humidity) and send them back to the user. To do this we kept the original physical body of the AR.Drone as well as the internal sensors and controllers, and equipped it with additional devices to extend its capabilities so it can match the project's requirements:

. Sensors: Attitude and Heading Reference System (AHRS) based on a 9DOF IMU including a compass (Razor 9DOF), GPS, Proximity sensors for collision avoidance (Sharp Infrared Range sensors), High Vision Camera with a remote shutter, Temperature and Humidity sensors

. Communication: 2.4GHz wireless transceiver to extend the range to ~100 m

. Control: GUI on PC (Fig. 3) with a 3D mouse (manual mode, for development) or autopilot (autonomous control mode)

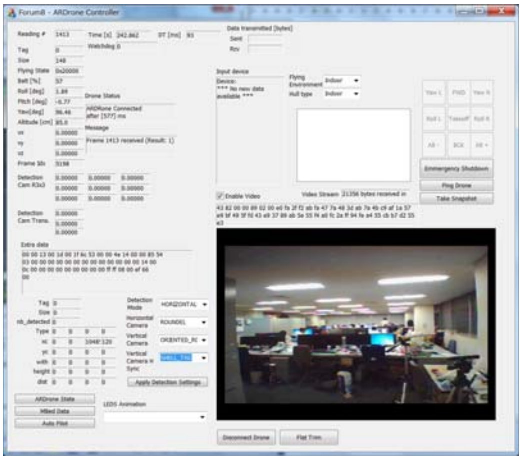


Fig.3 : ARDrone interface, with real time video feed from the drone (front camera)

3. Autonomous navigation and task scheduling

From UC-win/Road, a 3D-interactive Virtual Reality software for interactive virtual reality modeling for construction planning, urban planning, civil engineering and traffic modeling. In this project we use its Virtual Reality modeling capabilities to plan the drone tasks, and visualize its data in real time. For an effective and practical use of the system in the agriculture context (monitoring of crops), the presence on-site of the end user is not necessary: the *VR-Cloud* version of UC-win/Road allows him to check on the drone status or data in real time (Fig.4.a, 4.b), from virtually anywhere and anytime. For instance the user can be in a remote location and still be able to modify the drone "mission" (e.g. change of flight plan or rescheduling of tasks in case of change of weather).

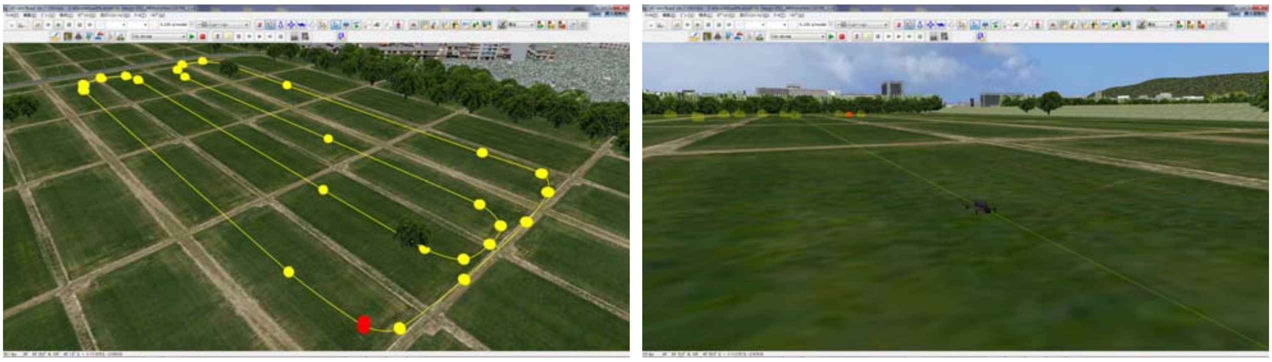


Fig.4.a, 4.b: Path planning in UC-win/Road

4. Autonomous control

The 3D path is planned using UC-win/Road, and defined as a series of waypoints (position: xi, yi, zi and heading θi), which are sent to the drone as a reference to follow. In that control mode, the default autonomous behaviors like hovering are disabled. From the waypoints, the drone computes a more refined path by linear or Bezier interpolation. The computation of the commands based on the definition of the waypoints is made in 3 phases:

. at each time step, the location of the nearest point on the interpolated path is estimated

. a pursuit point is defined at a fixed distance ahead of the nearest point (look ahead distance) by using the simple pure pursuit tracking algorithm(6).

. finally, the pursuit point coordinates are then estimated in the drone local reference frame to establish the (roll, pitch, yaw angular rates and vertical speed) to feed the AR.Drone attitude controller that computes the angular speed for each motor. The control architecture in manual mode(7) is given in Fig.5.

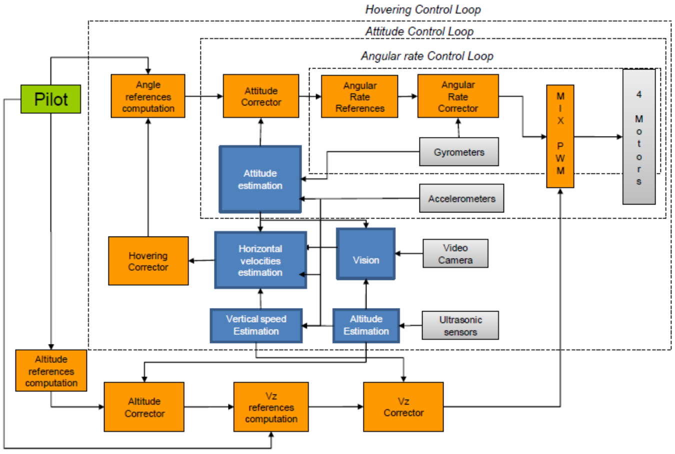
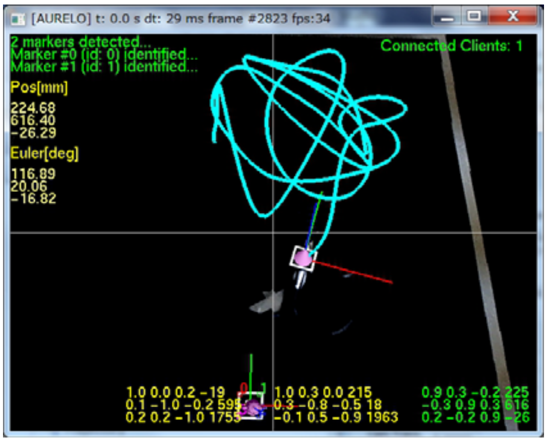


Fig.5: AR.Drone control architecture(7)

At anytime the drone will switch automatically to manual mode and land for safety when a problem is detected (loss of communication or flying over the transmission range), to avoid loosing the drone when carried away by mild to strong wind.

We chose to study the behavior of the drone in a controlled environment, to get rid of possible perturbation elements, like the wind or the GPS localization errors. Thus the development has been performed indoor, and to overcome the inability to use the GPS indoor, we use our absolute localization system AuReLo (**AU**gmented **RE**ality **LO**calization system). It is a multi-purpose tracking system based on AR (Augmented Reality), designed to track position andd orientation of stationary or moving objects, as well as laser spots, with a relatively good accuracy (1~2cm error at 2.5m range). The principle is quite simple; the AR technique allows to estimate the relative position/orientation of AR markers in the camera's reference frame. To track a moving target, we use two markers, one defining the origin of an absolute reference frame and the other one fixed on the object to track.

The Figure 6 shows the development tests of the autonomous control algorithm, for instance by an implementation of the autonomous hovering function over a specified target.



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[AURELO] t: 0.0 s dt: 29 ms frame #2823 fps:34
2 markers detected...
Marker #0 (id: 0) identified...
Marker #1 (id: 1) identified...
Pos[mm]
224.68
616.40
-26.29
Euler[deg]
116.89
20.06
-16.82
Connected Clients: 1
1.0 0.0 0.2 -19      1.0 0.3 0.0 215       0.9 0.3 -0.2 225
0.1 -1.0 -0.2 595    0.3 -0.8 -0.5 18      -0.3 0.9 0.3 616
0.2 0.2 -1.0 1755    -0.1 0.5 -0.9 1963    0.2 -0.2 0.9 -26
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Fig.6: Autonomous behavior: hovering over a specified area, tracking with AuReLo

The next step is to put this control algorithm to test in outdoor environment with the GPS, ideally with no wind. The system will then be ready for evaluation over an actual crops field.

5. Conclusion and Future Work

In this paper we presented the current state of development of an agriculture autonomous UAV controlled at a high level by a Virtual Reality software. The UAV platform used is the AR.Drone, designed initially for video gaming and home entertainment purposes. The main motivation of the choice of this drone was its low cost, easiness to handle and semi autonomous behavior like takeoff or landing, available in the original version. The first tests indoor showed the effectiveness of the drone to perform predefined tasks in an autonomous way and give good hopes regarding outdoor applications such as monitoring, inspection and surveillance.

The current drone configuration can lift only few grams payloads, which is not sufficient for loading additional sensors. For this reason we will use in the next project an octorotor UAV which maximum payload is about 1kg with 30 min endurance. Those specifications will make it possible to use an UAV in a wider variety of applications implying specific types of sensors like in telemetry or real time mapping of 3D environments.

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