# MANEKI-NEKO

## TEAM DESCRIPTION FOR IRAN OPEN UAV 2013 - TEHERAN, IRAN

Intelligent Autonomous Systems, University of Amsterdam, The Netherlands

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February 22, 2013

## 1 Introduction

The team *Maneki-Neko* is a cooperation between several institutes from the Netherlands. Several Dutch teams have participated in previous International Micro Aerial Vehicle competitions [2, 7, 18].

The first Dutch contribution to Micro Aerial Vehicle (MAV) competitions was the introduction of the first prototype of the DelFly at the first US-European Micro Aerial Vehicle Competition in Germany, September 2005 (see Table 1). The DelFly I[1] is a flapping wing MAV developed by a team of students directed by the MAVlab of the TU Delft. The TU Delft MAVlab researchers are very active in the MAV area, and recently introduced a hybrid UAV (with Team Atmos[2]) for the DARPA challenge.

The IMAV 2011 in the Netherlands was organized by the TU Delft and Thales Nederland, who persuaded many other Dutch institutes to join the competition. One of those teams was the UvA Drone Team. The Dutch team participating at the Iran Open 2013 consists purely of members from the Universiteit van Amsterdam, so this team is a natural continuation of the UvA Drone Team [16].

The UvA Drone Team participated successfully at the 2011 competition, where they displayed as only Indoor team navigation based on an online build map [3]. The paper

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[1] `http://www.delfly.nl/?site=Publications`

[2] `http://www.teamatmos.nl/the-challenge`

[18] presented at the IMAV 2011 conference was nominated for the best paper award.

| Institute | Teamname | competition | prices |
|---|---|---|---|
| TU Delft-Wageningen | DelFly[3] | MAV 2005 | Technology prize |
| TU Delft-Wageningen | DelFly / Horizon | EMAV 2007 | Best Flapping Wing Technology Prize |
| TU Delft-Wageningen | RoboSwift[4] | MAV 2008 | Demonstration |
| TU Delft | DelFly | EMAV 2008 | Best Fully Autonomous Indoor Micro Aerial Vehicle |
| TU Delft | DelFly | IMAV 2010 | Independent indoor flight |
| ” | DelFly | ” | Gathering data indoors |
| : | Horizon | ” | Fixed Wing outdoor flight |
| Radboud Univ. Nijmegen | BioMAV | IMAV 2011 | 3rd prize Indoor Pylon challenge |
| KLPD / NLR / RNA | KND | ” | 3rd prize Outdoor multiple MAV challenge |
| Univ. of Amsterdam | UvADroneTeam | ” | |

Table 1: Dutch teams at Micro Aerial Vehicle competitions.

As indicated in the Acknowledgements, the people from Amsterdam are supported by a number of Dutch institutes with software, algorithms, expertise and testing facilities.

## 2 Team Members

ARdroneMap was originally developed by Nick Dijkshoorn [3]. Camiel Verschoor has ported the ARdroneMap algorithms to the Robot Operating System (ROS)[5]. All other contributions will be integrated into this framework. Many other team members [10, 15, 9] have contributed to perception and control algorithms which leaded to this framework. The Iran Open 2013 gives the possibility to test several improvements made to accomplish this year's new challenges.

The work is distributed over the team as follows:

| Name | Phone | Contribution |
|---|---|---|
| **Camiel Verschoor** | +31652697911 | Path Following [17] |
| **Auke Wiggers** | +31653496175 | Multi-Robot Coordination |
| **Harrie Oosterhuis** | +31629358206 | Dynamic Dropzone |
| **Arnoud Visser** | +31653697548 | ARDrone Simulation [5] |

## 3 Platform

The Maneki-Neko team is participating in the competition with a standard platform provided by Parrot SA. The Parrot AR.Drone is a small affordable quadrotor with onboard stabilization. It is equipped with a MEMS gyroscope, a sonar attitude sensor and two cameras.

Fig. 1 gives an overview of the AR.Drone 2 platform. Several parts are indicated with small orange numbers, which are described in more detail in Sections 3.1 and 3.2 in Figures 2 and 3.

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[3] `http://www.lr.tudelft.nl/index.php?id=28237&L=1`

[4] `http://www.roboswift.nl/?page=design&lang=en`

[5] `http://www.ros.org`

Figure 1: The technical specifications of the AR.Drone 2 (Courtesy Parrot SA).

The AR.Drone 2 platform is used by our team as rapid development platform. Algorithms which are developed can be ported to other platforms, such as the platform of CrazyFlie, Flamewheel F450 or F550 or an Astec Pelican. These platforms are not available at the Universiteit van Amsterdam, but are available at the partner institutes. Easy porting should be possible by using standards as the Paparazzi flight controller[6] and software packages from the Robot Operating System (ROS).

## 3.1 Electronics

The AR.Drone is equipped with an ARM processor which runs an embedded version of Linux. The AR.Drone is stabilized by an advanced algorithm [1] which uses image stream from the bottom camera. Unfortunately, this background process consumes most of the on-board processing power.

Navigation is mainly done using the HD-images from the front-camera (see i.e. [10]), although the lower resolution bottom camera and sonar sensor can be used [3] as well.

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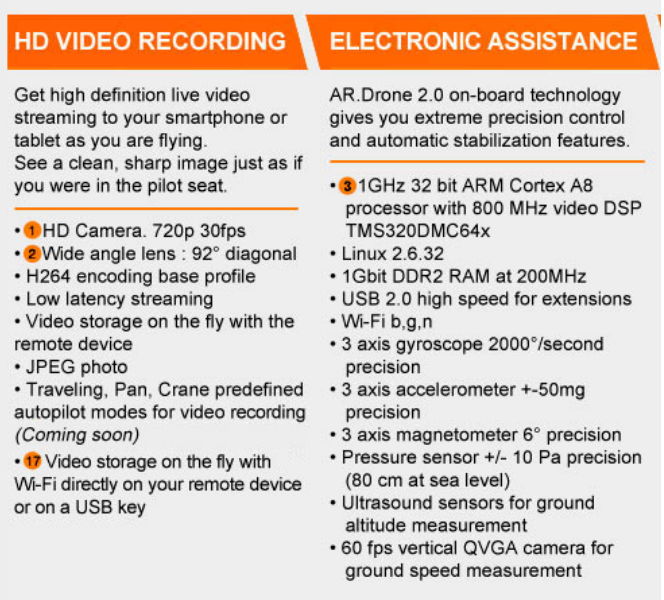
[6] `http://paparazzi.enac.fr/wiki/TU_Delft_-_Autonomous_Quadrotor#Teams`



**HD VIDEO RECORDING**

Get high definition live video streaming to your smartphone or tablet as you are flying.
See a clean, sharp image just as if you were in the pilot seat.

- ① HD Camera. 720p 30fps
- ② Wide angle lens : 92° diagonal
- H264 encoding base profile
- Low latency streaming
- Video storage on the fly with the remote device
- JPEG photo
- Traveling, Pan, Crane predefined autopilot modes for video recording *(Coming soon)*
- ⑰ Video storage on the fly with Wi-Fi directly on your remote device or on a USB key

**ELECTRONIC ASSISTANCE**

AR.Drone 2.0 on-board technology gives you extreme precision control and automatic stabilization features.

- ③ 1GHz 32 bit ARM Cortex A8 processor with 800 MHz video DSP TMS320DMC64x
- Linux 2.6.32
- 1Gbit DDR2 RAM at 200MHz
- USB 2.0 high speed for extensions
- Wi-Fi b,g,n
- 3 axis gyroscope 2000°/second precision
- 3 axis accelerometer +-50mg precision
- 3 axis magnetometer 6° precision
- Pressure sensor +/- 10 Pa precision (80 cm at sea level)
- Ultrasound sensors for ground altitude measurement
- 60 fps vertical QVGA camera for ground speed measurement

Figure 2: The electronic specifications of the AR.Drone 2 (Courtesy Parrot SA).

Flight control can be performed by propriety software of Parrot, by running the software implementation of the Paparazzi flight controller[7] on-board, or by mounting a Paparazzi control board on the robot (making the connection via the usb-connection of the AR.Drone board). All three methods have been tried and work quite well.

## 3.2 Mechanics

The AR.Drone is a robust platform, which survived many ambitious experiments in our laboratory. In case of damage, spare parts can be easily ordered.

The only modification in the structural design is a remounting of the front camera in the case of line-following [17].

The line-following experiments are expected to be performed at low altitudes between 1-2 meters. Therefore, an angle of approximately 45°is considered as optimal. By cutting away Styrofoam it is possible to set the front camera under a different angle.

## 3.3 Flight characteristics

The stable flight of the AR.Drone and a demonstration of some of our autonomous perception and control algorithms are available in our Qualification Video. This video is publicly available at YouTube[8].

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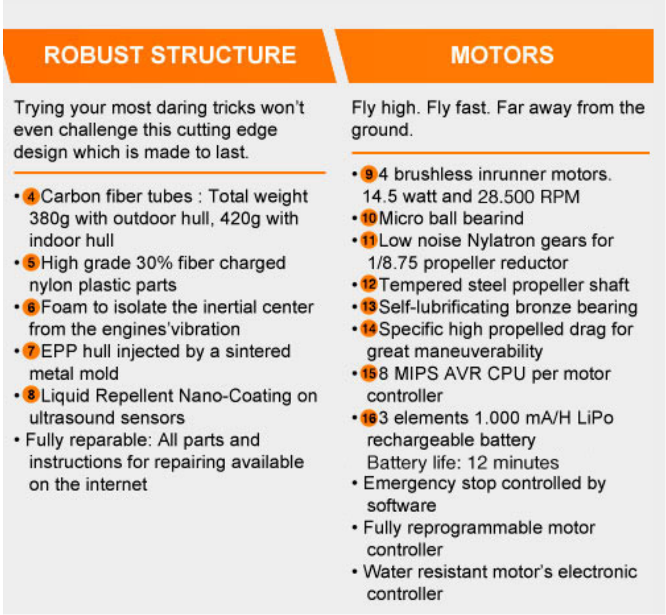
[7] `http://paparazzi.enac.fr/wiki/AR_Drone_2/getting_started`

[8] `http://youtu.be/yOj5HI6mji4`



**ROBUST STRUCTURE**

Trying your most daring tricks won't even challenge this cutting edge design which is made to last.

- ④Carbon fiber tubes : Total weight 380g with outdoor hull, 420g with indoor hull
- ⑤High grade 30% fiber charged nylon plastic parts
- ⑥Foam to isolate the inertial center from the engines'vibration
- ⑦EPP hull injected by a sintered metal mold
- ⑧Liquid Repellent Nano-Coating on ultrasound sensors
- Fully reparable: All parts and instructions for repairing available on the internet

**MOTORS**

Fly high. Fly fast. Far away from the ground.

- ⑨4 brushless inrunner motors. 14.5 watt and 28.500 RPM
- ⑩Micro ball bearind
- ⑪Low noise Nylatron gears for 1/8.75 propeller reductor
- ⑫Tempered steel propeller shaft
- ⑬Self-lubrificating bronze bearing
- ⑭Specific high propelled drag for great maneuverability
- ⑮8 MIPS AVR CPU per motor controller
- ⑯3 elements 1.000 mA/H LiPo rechargeable battery
  Battery life: 12 minutes
- Emergency stop controlled by software
- Fully reprogrammable motor controller
- Water resistant motor's electronic controller

Figure 3: The mechanical specifications of the AR.Drone 2 (Courtesy Parrot SA).

## 4 Contributions

This section gives an overview of the contributions that have been done by Maneki-Neko and its predecessors regarding autonomous navigation for unmanned aerial vehicles.

In the initial research [9], an attempt was made to pick an object and to carry it away. The object was allowed to be designed by the participants, so in this case a bright pink object was selected. The pink object could easily recognized by specifying a range in the HSV color space, which resulted in a single region of interest. The distance to the object was estimated by matching mask of several sizes against this object.

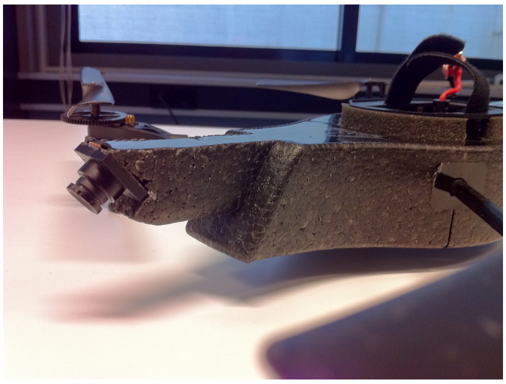
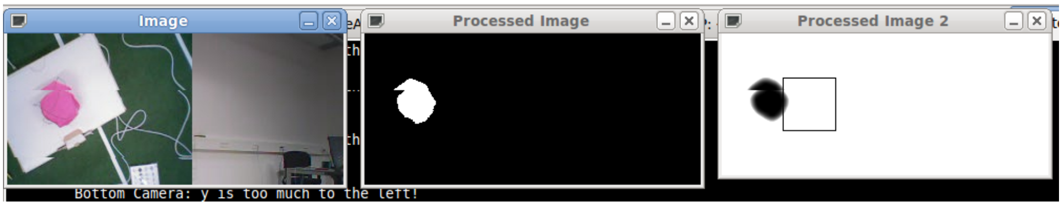


Figure 4: The modification of the front camera orientation of an AR.Drone.



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Bottom Camera: y is too much to the left!
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Figure 5: Recognition of the bright pink object with the bottom camera [9].

Once the location of the object was known, it had to be lifted up. The draft of the rotors is too strong to do this from above, so the AR.Drone has to maneuver to the side of the object, locate the object again with its front camera and fly over it. If successfully executed, a hook, mounted under the AR.Drone, would pick up the object. Part of this research could be reused in the DropZone mission.

The bottom camera was also used in the research presented at the IMAV 2011 conference [18]. The frames from the AR.Drones low-resolution down-looking camera are aligned together and drawn on a canvas object. The frames were analyzed for Speeded-Up Robust Features (SURF) that are invariant with respect to rotation and scale. Each feature is represented by a descriptor vector and its position, orientation, and scale in the image. A set of matches between the point features of two camera frames is used to estimate a homographic model for the apparent image motion. This model can be composed with the estimated motion of the rest of images in order to build a mosaic (see Fig. 6).

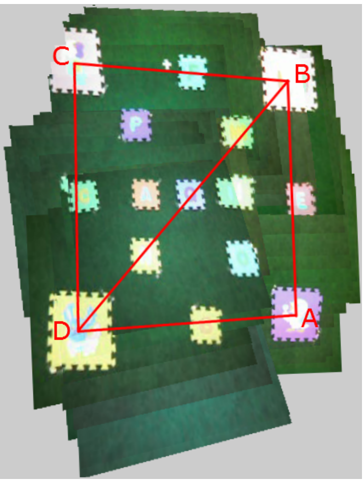

Figure 6: A mosaic of the texture of the ground, above a green field with distinctive markers [18].

One challenge within robotics is the simple task of autonomous navigating towards a goal without hitting obstacles, which is actually one of the mission elements of the 2013 competition. One of the proposed methods that try to solve this task uses artificial forces to guide the robot [15]. The robot is attracted by the goal, while obstacles spread a repelling force. The approach works, but does not give an optimal path. In this thesis the question was researched whether the guiding forces, initiated by a prior belief (see Fig. 7), could be improved by learning based on observations and experience.

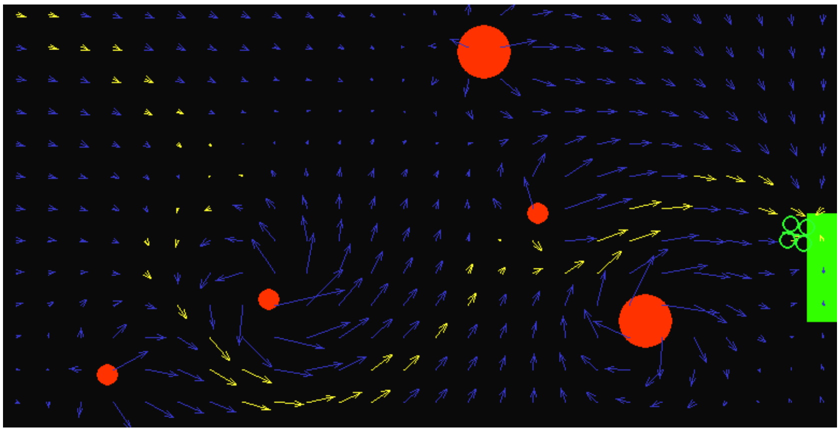

Figure 7: An example of a potential field, leading a drone towards a (green) goal [15].

Obstacles can also be avoided by analyzing the optical flow of the front camera [10]. By combining Shi-Tomasi algorithm with the Lucas-Kanade algorithm into Hartley's algorithm candidate positions of the ego-motion of the camera can be estimated [11]. A major limitation of Hartley's algorithm is that the algorithm cannot account for scale, such that all distance estimates are relative. Isaac Esteban dedicates a whole chapter of this thesis [6] on the propagation of errors of the initial scale estimate. See for instance Fig. 8 for Esteban's reconstruction of fountain without bundle adjustment and estimation of the scale based on the image.

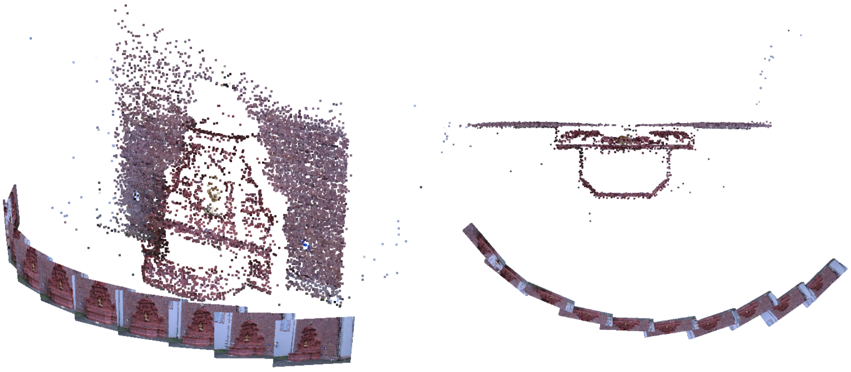

Figure 8: Reconstruction of a fountain by estimating the scale (Courtesy Esteban [6]).

Full 3D reconstructions are complex and computationally expensive. The reconstruction can be made more efficient and robust when certain assumptions about the environment and movements of the robot can be made. Dijkshoorn [4] demonstrates that by taking certain assumptions in the pose recovery, the accuracy of the more general OpenCV algorithms based on Euclidian, affine or perspective transformations can be outperformed.

## 5 Current Approach

For the Iran Open Flying competition the Maneki-Neko team will focus on three indoor mission elements: path following, obstacle avoidance and the dynamic drop zone.

The **path following** approach will be based on the initial work of Verschoor [17], which will be augmented with the line detection algorithms developed in the RoboCup Standard Platform league [8]. This algorithm is not only able to detect lines from different perspectives, but is also able to classify intersections of lines. This can be used to localize the AR.Drone along the square path.

The **obstacle avoidance** approach will be a combination of the work of [10] and [11]. This would give disparity maps. The challenge will be to convert the relative distance into a repulsive force, which could be included into a guidance field (which is equivalent with learning a navigation map).

The **dynamic drop zone** approach will be a combination of a ball following algorithm and a QR-detection algorithm [13]; equivalent with how Martijn Liem [12] combined EM-shift [19] with the Kanade-Lucas-Tomasi tracker [14]. The challenge here is to move stable above the dynamic drop zone.

## 6 Conclusion

The Maneki-Neko team can build on the experience of several institutes in the Netherlands and teams which competed in a variety of robotic competitions. For the Iran Open Flying competition the team will focus on three indoor mission elements: path following, obstacle avoidance and the dynamic drop zone.

## Acknowledgements

The Amsterdam members of the Maneki-Neko team are supported by students and researchers from other institutes of the Maneki-Neko team and institutes involved in Micro Aerial Vehicle research in the Netherlands, such as the Noordelijke Hogeschool Leeuwarden, Hogeschool Utrecht, Technical University Delft and the Dutch National Airspace Laboratory.

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