## Project Assignment “Autonomous Flight of MAVs”

One of the major challenges in the autonomous flight of Micro Air Vehicles is navigation in cluttered environments. Very good results can be obtained by using active sensors such as laser scanners or the Kinect in combination with a Simultaneous Localization And Mapping (SLAM) approach, e.g., [1]. However, this approach requires significant energy for the sensing and rather extensive processing and memory capabilities onboard. Hence, it results in shorter flight times / heavier MAVs.

In this project your team has to develop a more efficient, purely vision-based approach to autonomously navigate through an obstacle field. The algorithm will have to run on board the Parrot AR drone 2, a commercially available quad rotor equipped with a range of sensors. Importantly for the project, it has a single frontal camera. Hence, the developed algorithm concerns a monocular vision solution to obstacle avoidance.

**Figure 1:** picture of an obstacle field used in the IMAV 2013 competition (http://www.imav2013.org/).

There are various approaches to monocular obstacle avoidance, based on visual SLAM [2], bio-inspired optic flow [3], or imitation learning on the basis of a large visual feature vector [4]. These methods differ in the type of information extracted from the images, the amount of detail this information provides on the environment, and the computational effort involved in extracting the information.

It is your team's task to implement an existing or create a new approach to monocular obstacle avoidance on the AR drone. All teams involved in the “autonomous flight of MAVs” course will compete with each other at the end of the course. To this end, an obstacle field will be constructed in the “cyberzoo”. All teams will have their programs compete at a task of flying as often through the obstacle zone as possible within a fixed alotted time of 10 minutes. The team with the maximal covered distance wins the competition. When in the obstacle field, the control of the AR drone should be fully autonomous, i.e., no human intervention is then allowed.

**Competition:**

The competition will take place at the end of the course in the cyberzoo. Each team has an alotted flight time of 10 minutes to fly through an obstacle zone within the cyberzoo – the flight height is maximized to 2 meter. Figure 2 shows a sketch of the cyberzoo and a possible placement of the obstacles. Please note that in between runs obstacles may change place.

When the participation of the team starts, the team enters the team area of the arena to install their computer and other possible equipment (yellow). The drone should then take off and fly through the obstacle zone (green square). If the drone goes outside of the obstacle zone, the team should be able to command the drone to hover. A judge then will have the drone yaw into a chosen direction, and the autonomous control has to be switched on again. It is not allowed to have the drone turn in circles in the obstacle zone. The team's performance is the covered distance in the obstacle zone within the flight time of 10 minutes. This covered distance is determined with the help of the Optitrack motion tracking system.

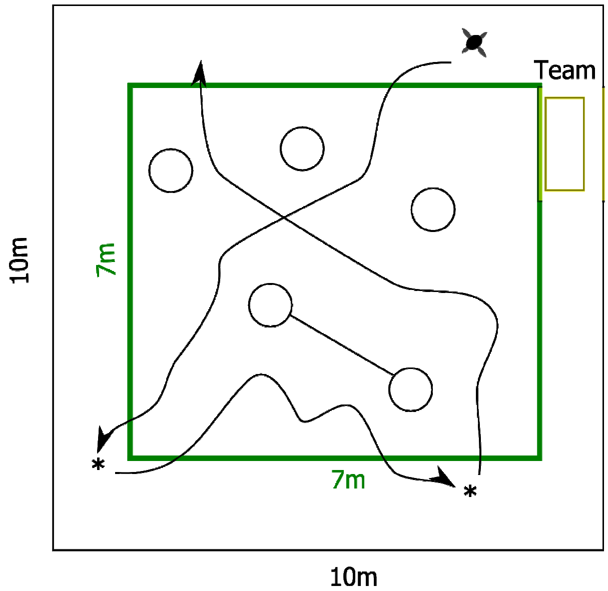


**Figure 2:** competition setup in the cyberzoo. Outer black lines represent the nets, inner green lines the obstacle zone. Yellow area indicates the position of the team. The figure shows an example trajectory. After passing through the obstacle zone, the quad rotor is manually directed in a new direction by a judge (see * locations in the example).

### Deliverables:

There are two deliverables for the project:

(1) A short article explaining the chosen / designed approach, also comparing it with respect to approaches in the literature. The article has to be written in Latex with a given template, and be in between 4 and 6 pages. (50% of the project grade)

(2) A C-program that permits the Parrot AR drone 2.0 to avoid obstacles in an indoor obstacle zone. The program will be evaluated on the basis of the distance covered by the drone and the number of collisions within the 10 minute flight time of the competition. The 1$^{st}$ and 2$^{nd}$ place in the competition get a bonus. (50% of the project grade)

### Methods

The vision-based navigation method has to be implemented within the Paparazzi open autopilot project [5]. Paparazzi has been adapted to enable the autonomous control of the Parrot AR drone 2. It allows to put embedded control and vision software onboard the AR drone. The Paparazzi vision framework for the AR drone contains a template example in C-code that can be adapted by the team for the indoor navigation.

Teams can:

- Use offboard vision computation.
- Use the optitrack system for control.
- Make modifications to the environment.

The extent to which a team uses these elements is part of the evaluation.

**References**

[1] Autonomous multi-floor indoor navigation with a computationally constrained MAV S Shen, N Michael, V Kumar Robotics and automation (ICRA), 2011 IEEE international conference on, 20-25.

[2] Monocular vision SLAM for indoor aerial vehicles, Celik, K. ; Soon-Jo Chung ; Clausman, M. ; Somani, A.K., IEEE/RSJ International Conference on Intelligent Robots and Systems, 2009. IROS 2009. Page(s): 1566 - 1573

[3] Obstacle detection using optical flow, Toby Low and Gordon Wyeth, in Proceedings of the 2005 Australasian Conf. on Robotics & Automation, 2005.

[4] S. Ross, N. Melik-Barkhudarov, K.S. Shankar, A. Wendel, D. Dey, J.A. Bagnell, and M. Hebert. Learning monocular reactive uav control in cluttered natural environments. In IEEE International Conference on Robotics and Automation (ICRA), 2013.

[5] http://wiki.paparazziuav.org/wiki/Main_Page

**Evaluation of the project assignment.**

The evaluation of the two parts of the assignment is done with the following rubric. Yellow is the code / performance part of the evaluation, green the article part. The right column shows the percentage weighing per row.

| | Fail – 4 | Adequate – 6 | Good – 8 | Excellent – 10 | |
|---|---|---|---|---|---|
| **Performance – qualitative** | Not flying at all, only hover or circling, continuous collisions | Passing at least once through the obstacle zone without a collision or with a “mild” collision | Passing several times through the obstacle zone, with only occasional collisions / restarts | Passing continuously through the obstacle zone with max. 1 / 2 “mild” collisions | **20,00%** |
| **Performance – quantitative** | 0 – 7 meters | 7 – 28 meters | > 28 meters | > 42 meters, or 1st / 2nd prize | **10,00%** |
| **Task difficulty** | Offboard processing, and Optitrack for control, and additions to the environment that make obstacles extremely easy to detect. | Offboard processing or additions to the environment that facilitate the task. | All solutions not in any other category (e.g., Onboard processing with Optitrack for control). | Onboard processing, and no change to the environment, and no Optitrack for control. | **10,00%** |
| **C-program** | Not compiling / not running / no sensible control logic present in the code / no clear commenting / structuring | Program runs with only occasional crash / memory leak, poorly commented / structured | Program runs without problems, comments are present in the code, it is structured in a sensible way | Program runs without problems, is well-commented and documented, is suitable for future expansions, could be committed to Paparazzi | **10,00%** |
| **Discussion of available approaches in the literature and proposed approach** | Hardly any discussion of the literature, only the obligatory references, rudimentary explanation of the proposed approach | Main approaches given in the course are discussed using the references from the course, rough comparison of the properties of the approaches, description of the proposed approach may not allow reimplementation | Various approaches are discussed, including references not given in the course, reasons for the proposed approach are given, and it is described in sufficient detail to get the gist | Extensive overview of the literature is given, with many references not given in the course, analysis of these approaches logically leads to the proposed approach that is described in sufficient detail for reimplementation | **10,00%** |
| **Quality proposed approach and its description** | Approach is not well-motivated / is likely not to work | Reasons are given for choosing an approach in the literature, and is implemented as is. | Reasons are given for choosing an approach in the literature, which is adapted to the competition at hand. | Approach is well-motivated and considerably novel compared to existing approaches, and could lend itself for scientific | **15,00%** |

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| | | | | publication | |
| **Preliminary tests / analysis** | No preliminary tests have been performed / are mentioned | A few preliminary tests have been performed and are mentioned in the report. A detailed analysis of the results and a motivation for iterations of the algorithms is lacking. | Preliminary tests have been performed and are mentioned in the report. A detailed analysis of the results is given and iterations of the algorithms are explained. | Extensive tests have been performed, testing the sensitivity of the performance with respect to the various parameters in the approach. Iterations of the approach are explained and the final approach is tested also extensively. | **15,00%** |
| **Article** | Badly structured, hard to follow, many English mistakes. | Brings across the central message, but contains parts that are difficult to understand due to structure, English, unclear figures etc. | Well-structured and clear text, figures sufficiently clear, a few passages that may need improvement. | Well-structured, clear, well-written, correct English, could be submitted as a conference paper. | **10,00%** |