PROPOSAL of a
RoboCup Brazil Open Flying Robot Trial League

Guidelines, vision and goals.

1. Introduction

The use of flying robots has become popular in recent years, and its range of applications tends to increase strongly in the next decade. The need to develop new technologies for these vehicles (i.e. the mechanical, electrical and computer dimensions) has stimulated research in this segment by several new emerging groups in Brazil, in Latin America and around the world. In this context, CBR (Brazilian Robot Competition), LARC (Latin American Robot Competitions) and RoboCup seek through this competition stimulate the development of applied research in autonomous robotics with unmanned aerial vehicles (UAVs).

This proposal aims to introduce in CBR an autonomous flying robot competition league. In this league, teams will build a flying robot capable of racing in a preset field while avoiding obstacles. The flying robots will also need to perform predefined tests to obtain points similarly to the @Home RoboCup League. This proposal and its tests will be described and detailed in the following sections.

2. Vision and Goals

To understand the long-term vision and the main goals of this new league, one must first analyze the existing UAV competitions. The number of international competitions involving flying robots has increased dramatically in recent years. RoboCup has always distinguished itself for the originality and long-term vision of its robot competition leagues. Thus, it is of utmost importance to show the long term vision for such a RoboCup league, the research challenges involved, the unique selling points of such league challenges w.r.t. to other flying robot competitions. Nowadays, the most renowned existing Drone competitions are:

- UAV Challenge (https://uavchallenge.org/) - It is a pick and drop challenge aiming to deliver medical packages through UAVs. It requires the use of teleoperated flying robots, instead of autonomous flight. There is no multi-robot or human interaction. It usually uses fixed-wing flying robots for outdoor environments.
- euRathlon (http://www.eurathlon.eu/), or ERL Emergency Robots - It is a competition that requires three types of robots (aerial, ground and aquatic). Naturally it is performed in outdoor environment and it aims to survey a disaster site, collect environmental data, and identify critical hazards. Despite it uses three different robots and it uses multi-robot interaction, It has no human-robot interaction. It is an autonomous robot competition.
- MAAXX Europe (http://maaxx-europe.com/) - It is an autonomous race competition. It aims to perform autonomous UAV indoor flight. It has no human-robot interaction and it is not a multi-robot competition.
- IARC (http://www.aerialroboticscompetition.org/) - Is is a UAV competition aiming to improve UAV technology. It usually changes its challenge every time a team completes the required task. It exists since 1991 and the past missions were mission 1 (1991-1995), mission 2 (1996-1997), mission 3 (1998-2000), mission 4 (2001-2008), mission 5 (2009), mission 6 (2010-2013). The current mission is mission 7 since 2014. It is multi-robot, autonomous and applied to indoor environment. It has no clear future w.r.t. how this competition will become due to its changes.

- IROS Drone Challenge (http://ris.skku.edu/iros2017racing/) - It is an autonomous UAV flight race with obstacle avoidance. It is not a multi-robot competition and has no human-robot interaction.

Table 1: Existing UAV Challenges

Competition	UAV Challenge	euRathlon	MAAXX Europe	IARC	IROS Drone Challenge
Objective	pick and drop medical packages (mainly).	survey a disaster site, collect environmental data, and identify critical hazards.	autonomous UAV indoor flight race (no obstacle avoidance).	Game competition (obstacle avoidance and multi-robot interaction).	agile autonomous flight of drones in daring environments (with obstacle avoidance).
Control	Teleoperated	Autonomous	Autonomous	Autonomous	Autonomous
Multi-robot	No	Yes	No	Yes	No
Human-Robot	No	No	No	No	No
Environment	Outdoor	Outdoor	Indoor	Indoor	Indoor

Table 1 summarizes the characteristics of each challenge. Comparing the existing competitions, two strong characteristics are not addressed by most of the challenges: multi-robot and human-robot interactions. This latest one is not seen in any of the aforementioned competitions. Mainly, the research issues that are addressed nowadays are pick-and-place tasks, surveillance, data collection, racing and autonomous flight with obstacle avoidance.

Among the still existing and researched challenges, there are the following: robust flight controllers (trajectory, altitude and pose), robust localization GPS-independent and Tracking Camera System-independent, a high processing embedded system, long period of battery autonomy. Such issues are already being researched by international groups. These strong research groups worldwide would potentially be interested to participate in such league. To name but a few, some of the groups are:

- Prof. Davide Scaramuzza's group (Robotics and Perception Group, University of Zurich, Switzerland);
- Prof. Martin Saska's Group (Multi-robot Systems, Czech Technical University in Prague, Czech Republic);
- Prof. Vijay Kumar's group (GRASP lab, general robotics, automation, sensing & perception laboratory at Penn, USA);
- Prof. Nora Ayanian's group (ACT Lab, USA);
- Prof. Lorenzo Sabattini's group (ARSControl - UNIMORE, Italy);
- Prof. Antonio Franchi's group (LAAS-CNRS, RIS team, France);

Human-robot interaction and multi-robot cooperation without global tracking camera system are issues that must be addressed and researched in a long-term vision. As aforementioned, the multi-robot cooperation problem is beginning to be addressed in existing competitions. Thus, the difference of this new league is the human-robot interaction and the multi-robot interaction with autonomous UAV flight.

The long-term vision of this league is to stimulate the growth in the autonomous flight technology of aerial robots (UAVs) especially w.r.t. the interaction between UAVs and humans. This competition will have a 2050 theme called "Flying Robot Companion", enabling UAVs to become as useful as flying animals were in the past and more. To this end, by 2050 flying robots should aid humans in different tasks such as:

- Long-distances human following for surveillance and assistance;
- Package transportation and delivery among companies or between companies and users; (that could be integrated with RoboCup @Work results);
- Reliable and Secure Delivery of provisions as red-cross activities or UN interventions;
- Human and Environment protection (self surveillance);
- Human care (that could be integrated with RoboCup @Home results);
- Search and Rescue (that could be integrated with RoboCup Rescue results).

All of these tasks must put the UAV in indoor or outdoor environment, enabling the UAV to be aware of obstacles, other flying robots, other humans and environment conditions. The development of autonomous, reliable and secure companion flying robots is a cutting edge research that will be suitably explored and developed in this RoboCup category that has potential to integrate many others RoboCup categories.

Aiming the long-term vision, we first propose a short-term vision in order to analyse the competitors level and to stimulate the brazilian community regarding the existing issues regarding flying robots. As a short-term vision, this proposed RoboCup League aims in its first edition to stimulate secure autonomous flight with robust control and a human-robot interference, GPS-independent localization system for indoor flight and multi-robot interaction. These tasks must be, at first, mastered so the human-robot interaction can happen without incidents. To that end, we propose for the Brazilian Trial RoboCup League of Flying Robots a competition divided in three challenges aiming to overcome the aforementioned issues.

3. Teams

The teams that may participate in this league can be formed by an arbitrary number of team members at any level of education, noted that the responsibility for operating the flying robots meets all legal requirements, particularly the resolutions of ANAC (Brazilian Agency for Commercial Aviation Regulations). It is mandatory that all members of the teams are linked to an educational (and/or research) institution. There is no age limitation for the team members.

Each team will have a captain who will be responsible for placing the aircraft at the start locations indicated by the judge. The captain will also enable the start of the match and the landing of the flying robot. To access the arena the captain has to be wearing appropriate helmet and goggles (Personal Protective Equipment - PPE).

Each team will have a work area consisting of a table, chairs and a power strip. The teams also have access to wireless Internet in their work areas. During the waiting time between races, teams can work on their flying robots freely within the area designated for each group.

To register, teams must submit a document describing the development and operation of the flying robot in the competition format (TDP - Team Description Paper), and this should be accepted by the organizing committee. The TDP should describe all the relevant mechanical, electronic and computer system details, focusing on developments carried out by the group. They will not be accepted TDPs addressing superficially the technologies employed.

4. Flying Robots

Each team may participate in the competition with one (1) single flying robot that has been the target of research and/or development by the members of the participating teams, using any type of technology and any number of sensors, processors and actuators, observed that:

- During the tests the flying robots must act autonomously, i.e. without any external control or human intervention;
- It will only be allowed multi motor flying robots propelled by electric motors and power via batteries embedded in the robot. It is forbidden the use of helicopters and vehicles with combustion engines or gas balloons; The flying robots can have a maximum weight of 25 kg and the maximum distance between the axes of the helices of 450mm;
- The flying robot must be able to maintain a fixed position relative to the ground at a minimum height of one (1) meter;
- The use of any type of control hardware and embedded sensing is permitted provided they do not offer risk to participants or the public due to the emission of radiation or other signal level considered unsafe to humans;
- During the challenges, it is forbidden the use of wires, cables and/or umbilical cords, either for power, communication or any other purpose;

Although the flying robot must act autonomously during the challenges, the team must constantly keep remote supervision of the flying robot, according to the current legislation, ensuring the resumption of flying robot control by any technical problems and/or instability. The team should be able to start or stop the flying robot to the referee's whistle signal through the radio remote control.

It is important note that the flying robots should demonstrate the ability to adapt to conditions that exists in the real world, dealing with situations such as lack of ideal lighting conditions in the environment, people transiting around the arenas, etc.

5. The Competition

The aim of the competition is to stimulate the development of technologies for autonomous flying robots. The main objective is to stimulate the autonomous flight applied to surveillance and robust to human and obstacles interference. The competition will require from the flying robots skills such as:

a) The ability to maintain stability and balance even in the presence of human interference;
b) The ability to follow trajectories while avoiding obstacles;
c) The ability to work with ground robots and land in mobile platforms.

In order to stimulate the development of these skills, the competition is divided into three distinct challenges, which are described in the following subsections. It is not mandatory for the flying robot to participate in all challenges. However, all challenges will count points for the competition. The winner team will be the one that accumulate more points at the end of the 3 challenges.

The differences from this league and the Robot Rescue MicroAerial robot challenge are:

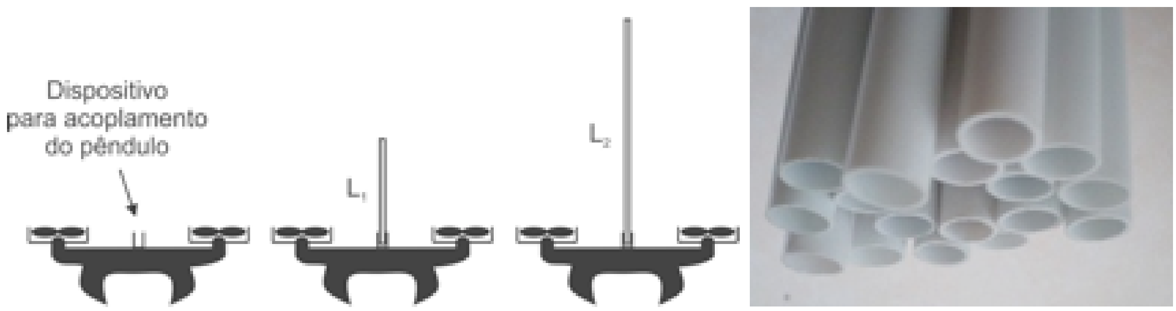
1. This is an entire league using mainly a flying robot, and it is not just a part of a ground robot major league;
2. The ground robot used in this league will be a tool used in one of the three challenges;
3. The ground robot and the flying robot will have to perform tasks in a coordinated fashion;
4. There is a human-autonomous robot interaction in the first challenge of this league;
5. The weight of the flying robots used in this league is 25kg;

6. The flying robot localization will be performed without the aid of GPS or External Camera Belt.

5.1 CHALLENGE 1: Maintenance of stability and balance

In this challenge the flying robot will need to stabilize its pose in a predefined height and maintain it even adding a set of pendulum with different sizes. As illustrated in Figure 1, the flying robots should have at its top a device for coupling an inverted pendulum. In this device it will be coupled hollow tube-shaped pendulums in ABS plastic (or similar) with circular section of external diameter equals to 1 cm and a variable length (L). The coupling device must allow immediate fitting of the pendulum without screws or any other fastening structures. It can not have more than 5 cm in height and it must allow free rotation of the pendulum without any resistance in 2 axes. The adequacy of flying robots for receiving the pendulum is the responsibility of the teams, using the technology of their choice.

The team can instrument the pendulum with any type of sensor(s) (e.g. potentiometers, inclinometers, etc., with arbitrary precision). They must be able to actively detect the pendulum tilt in two dimensions (x and y). It is the team's responsibility the interference that the weight of these sensors and their cables may cause in the pendulum stability and in the flying robot's performance.



(a) (b) (c) (d)

Figure 1. Positioning of the inverted pendulum to the challenge of stability and balance: a) flying robot with the device for coupling the inverted pendulum; b) flying robot with inverted pendulum L1 size; c) flying robot with inverted pendulum L2 size; d) pendulum examples.

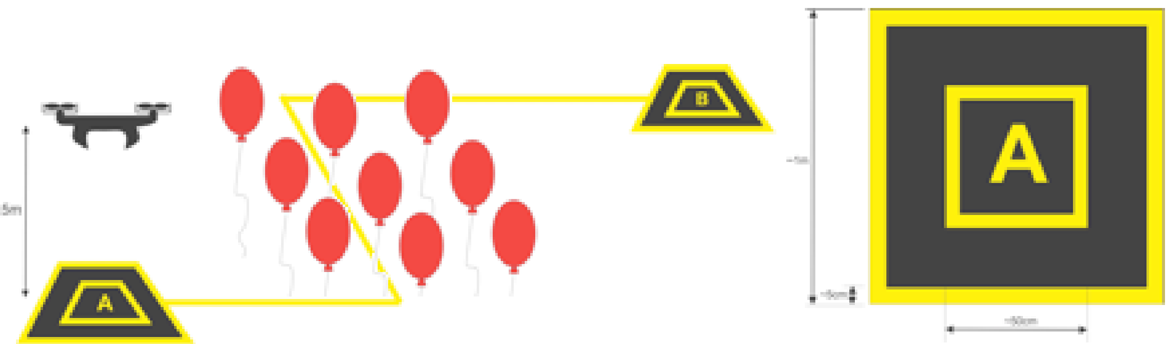
To start the test, the flying robot should position itself in a stable fashion flying 1m from the ground to have the pendulum manually engaged by the team captain overseen by the judge. The pendulum will be released by the team captain at the command of the judge always in approximate position of equilibrium. Once the pendulum is released by the team captain, the flying robot should demonstrate the ability to implement the control actions necessary to keep the pendulum in the equilibrium position. It will be considered balanced, a pendulum that does not fall for a minimum of 10 seconds.

The first round of the challenge will start with a size of pendulum L = 50cm, which must be balanced by all participating flying robots. Existing two (2) or more teams that have completed this round, the pendulum size will be increased and a new round begins. The pendulum size will be successively increased by new rounds up the maximum size of 200cm and/or until there are no more flying robots able to balance it. The score of each team will be assigned according to the size of the largest balanced pendulum by the team, getting 0 points the team that can not balance any pendulum and 200 points the team to balance the biggest one.

Reference Video: https://www.youtube.com/watch?v=ML4woERjvlk

5.2 CHALLENGE 2: Trajectory Tracking with Obstacle Deviation

In the second challenge the flying robot will take off from a local A, demonstrate the ability to follow an arbitrary path, bounded by a line on the ground, flying at a stable height at 1.5 m, and land on a site B in the same room. As illustrated by Figure 2a, there will be coloured balloons arranged in an arbitrary fashion in the arena, tied up on the ground with twine at said height. The flying robot must perform the path without breaking or even touching the balloons. The areas for takeoff and landing (Figure 2b) will use the typical heliports symbology (yellow squares on black surface) and will be built in MDF wood painted black with yellow soil demarcation tapes. The letters "A" and "B" will be written with ribbons at the locations to differentiate the landing area from the takeoff area. The flying robot must be positioned always above the line, not laterally. The line is marked on an approximately flat surface. The line will start immediately in front of the starting area. The floor will not receive any special treatment (it will be used the local available floor). There will be no previous knowledge its aspects (color, texture, consistency, etc.). The line will be demarcated using standard yellow soil demarcation tape. The test will not be considered complete until the flying robot hover within the demarcated area as "B".
The flying robot will be allowed to make one, and only one, initial overflight in the arena to map the obstacles and determine the best route to accomplish the challenge successfully or, at least identify the landing position. It is part of the challenge the ability to consider the possible movement of the balloons caused by the displacement of air generated by the flying robot actuators.



(a) (b)

Figure 2. Illustration of trajectory tracking with obstacle avoidance challenge: a) the flying robot should move from "A" to "B" position in a place with balloons; b) approximate dimensions of the landing and takeoff areas.

Each team will have three attempts to complete the challenge, starting with 300 points. Each unsuccessful attempt that involves the return of the flying robot to the initial "A" position will result in the loss of 100 points. In addition, each touch of the flying robot in an obstacle will result in one (1) failure of the team that deducts 5 points. Each balloon burst through contact with the flying robot will result in five (5) fouls for the team, cashing 20 points up to the zero limit. The challenge will not be considered complete until the flying robot hover within the demarcated area as "B". The maximum time to complete the challenge will be ten (10) minutes.

5.3 CHALLENGE 3: Multi-robot Surveillance

In this challenge, the goal is that the flying robot land in a mobile landing platform. The flying robot will take-off from a point "A" and land in a point "B" located in the top of a ground mobile robot. The ground mobile robot will perform a predefined trajectory given by the league rules a few months before the competition. The flying robot will take-off after the ground mobile robot reaches the middle of the trajectory. After the take-off the flying robot will track the mobile landing platform and descend while the ground mobile robot is moving. The ground mobile robot will follow the predefined trajectory at a speed of 0.3 m/s. In the arena, there will be obstacles for the flying robot to avoid displayed in an arbitrary fashion. This can be seen in Figure 3. To complete the challenge, the flying robot must move at a distance of 1.5 m from the ground. The team will be responsible for the ground mobile robot's construction. The construction of the ground mobile robot platform should fit in a box of 50x50x50cm. The robot can be either holonomic or non-holonomic, but should follow the change on orientation determined by direction of movement of the trajectory. During the challenge the flying robot is allowed to communicate with the ground mobile robot in order to coordinate the landing.

Every team that land in the ground mobile platform will be considered for scoring. The score will be awarded proportion to the time spent by the team to complete the challenge, receiving 200 points the team that makes the challenge in shortest time. In addition, each touch of the flying robot in an obstacle will result in one (1) failure to the team that deduct 5 points. Each balloon burst through contact with the flying robot will involve five (5) fouls for the team, cashing 20 points up to the zero limit.

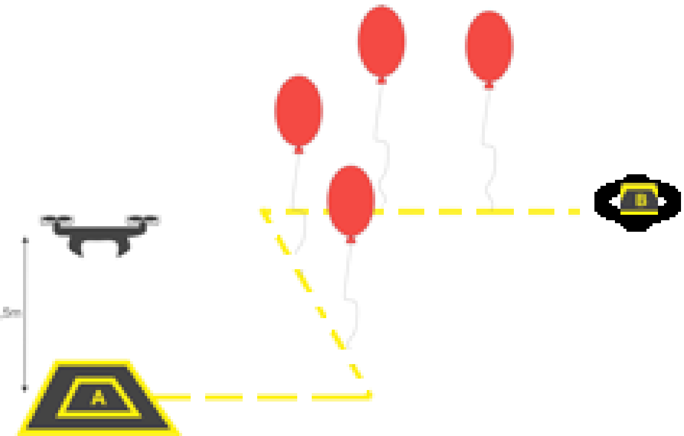


Figure 3. Illustration of the challenge of multi-robot surveillance: the flying robot should move from "A" to the ground mobile platform "B" while dodging obstacles.

The team may restart the race at any time. However, the time will not be interrupted and the number of fouls will not be restarted. At every restart, the flying robot must takeoff from point "A" while the load will be positioned again in the starting location.

5.4. ULTIMATE CHALLENGE: Human Interaction

In this ultimate challenge, only the teams that achieved more the 400 points will be allowed to participate and will receive a 200 extra points if the challenge has been completely done. The goal here is that the flying robot interacts with a human being, recognizing its figure and receiving orders.

The flying robot will take-off autonomously from a point "A", near to a human operator, and stand by. The human operator will give a command to the flying robot, which can be a voice or gesture one, that will activate an action of "follow me". After that, the operator will follow a pre established trajectory, in a low speed. The flying robot should stop as the operator stops, at any time. After execute the trajectory, the operator will stop and give a "land" command which will be followed by the flying robot.

The human operator will be the league judge, wearing appropriate helmet and goggles (Personal Protective Equipment - PPE).

6. Arena

Efforts will be made by the organizing committee for the competition to be organized in an area free of obstacles with an approximate minimum space of 10m x 10m, with approximate height of 3m. There will be arranged nylon safety nets (or related material) around the arena as a form of protection for the public.

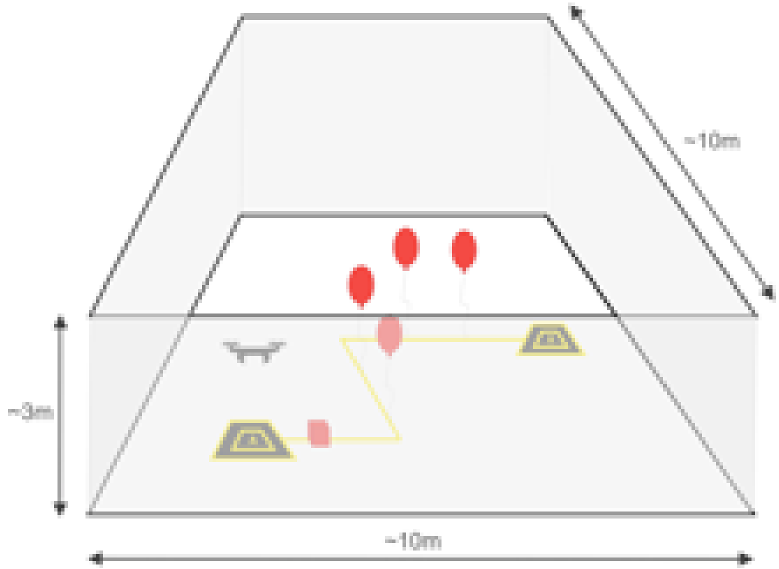


Figure 5. Illustration of the arena.

7. Materials Required

The following materials will be provided by the organizing committee:

- 01 (one) nylon protective net (approximately 120m2);
- 01 (one) tape of at least 2m (ideally 10m);
- N ABS plastic hollow circular tubes (or equivalent) with circular section and outer diameter of 1cm, where N equals the number of teams, with length of 50cm, 100cm, 150cm and 200cm;
- An arbitrary number of floating colored balloons fixed by a string of approximate length 1m and tied to weights;
- 02 (two) platforms (landing / takeoff) of 1m x 1m in MDF (perfectly straight) with the surface painted in black;
- 05 (five) yellow tape rolls for ground demarcation and ~ 5 cm thick;
- 01 (one) whistle;

8. Omissions

Situations not provided for in the rules (and/or questions regarding the interpretation of these rules) may be clarified by the organizing committee and the judges. Their statement in the matter is final.

9. Fair play

The characterization of the lack of fair play of a team and/or its members by the organizing committee at any time will entail the adoption of sanctions that may include (but are not limited to): warning, loss of points, elimination of round, elimination of competition, event banishment by an arbitrary number of issues. The penalty adopted by the organizing committee will consider the seriousness of the transgression.

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