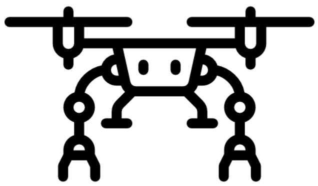

FIRA Air - Emergency Service Indoor Competition Rules (Pro)

Version: 6 Jan 2019

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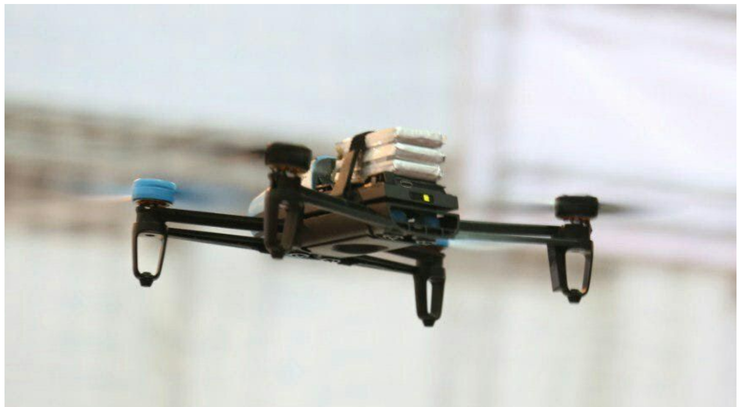
Abstract

The focus of the FIRA Air - Emergency Service competition is encouraging researchers to develop an autonomous navigation system for drones in urban environments. A suitable drone for this situation should be capable of vision-based navigation in presence of obstacles. Therefore, In the FIRA AIR 2019 competition, 5 different mission elements are designed to test the performance of drones for various real-world applications: Visual positioning in GPS-denied environments, Obstacle detection/avoidance, a medicine package delivery, Tall building, and Electrical tower inspections.



Latest Version of the Rules

The most recent official version of the rules of the FIRA Air - Emergency Service competition is always available here.

FIRA Air - Emergency Service

The goal of FIRA Air - Emergency Service competition is encouraging research teams to solve existing challenges in developing a smart and robust drone in both commercial and industrial applications. While drones are widely used for aerial imaging, there are still lots of challenges when it comes to an autonomous, reliable and secure solution. Overall most of these difficulties are related to localization, exploration, and intelligent navigation in dynamic environments.

Nowadays, drones are used for carrying packages in well-defined conditions and rural area but doing the same task in an urban environment is a lot more challenging. Tall buildings and communication equipment in the urban environment cause electromagnetic interference which can weaken satellite signals (GPS/GNSS) and thus can lead to great error in localization and navigation. In such situations, additional positioning method is required, and as most of the drones have an imaging camera, positioning based on the machine vision is one of the better choices. As an example, a reliable aerial package delivery system in the urban environment should be able to detect obstacles and avoid any collision. Delivering a medicine package in emergency situations inside a high traffic area is a real-world application of aerial package delivery using drones.

Figure 1, A Picture of an “Ambulance Drone“ from https://www.springwise.com/

Another practical application of drones is regular inspection of equipment installed on hard-to-reach locations. Currently, the inspection is done manually; a professionally trained operator is needed to control the drone to take pictures of the equipment from different angles. The same procedure can be done automatically which will result in simultaneous usage of several drones, faster operation, and more accurate results.

Rules of the Game

Rules of this competition are explained in this chapter. These rules are directing to develop a new system for autonomous navigation of drones using computer vision and without relying on GPS/GNSS data.

Physical specification of the drone must abide by the rules below. Otherwise, the drone is not allowed to take part in the competition.

- ❏ The size of the drone (including propellers) should be smaller than 100 cm.
- ❏ The weight of the drone (when flying) should be less than 3.5 kg.
- ❏ Only electric motors and actuators are allowed, using fuel-based motors is not allowed.

There is no limitation on the type of drone (airship, helicopter, ...) except that the drone should be capable of vertical flight.

Based on the competition venue, It is possible to have a level of magnetic or electromagnetic interference in the playing field. Although the OCs will try their best to prepare the field with the best possible condition, it is recommended to have a complementary sensor system for compass reading (heading) and low dependency on wireless connections (wifi).

For general specifications relevant to all FIRA events (e.g., playing field, lighting, and responsibility of the referees) please refer to General - FIRA Laws of the Game.

[FA-1]: Game Structure

This competition consists of 2 stages: preliminary and final. Missions get more complex as progressing to higher stages. All teams will participate in the first stage (preliminary), and according to the scores, a selection of teams would enter the final stage. The previous scores in the preliminary will be reset and only scores in the final stage will determine the winner. In each stage, the technical committee will decide the arrangement of mission elements and difficulty level.

The competition in each stage will have a collection of 5 mission elements:

- Visual-based navigation
- Obstacle detection/avoidance
- package delivery
- Tall building scaning
- Electrical tower inspection

Each stage consists of several mission elements which have a specific order and should be carried out in that order. A team can take part in all mission elements or only a few of them. For example, suppose preliminary stage has 5 mission elements, a team can perform the mission elements 1-2-4-5 or 2-4, but if the order is 1-2-5-4, the mission element 4 will not be scored.

A team would have 2 separate time slot in each stage to try the mission elements. A time slot is 20 minutes in total, consist of 5 min setup and 15 min run time. During the specified time, each team can try each mission 3 times, and the highest score among three attempts would be the score for that time slot. the final score of the stage is calculated by this formula (TS1 is the time slot 1):

$$Stage\ score\ =\ 1.5 * Max\,(TS1_{Score}\ ,\ TS2_{Score})\ +\ 0.5\ *\ Min\,(TS1_{Score}\ ,\ TS2_{Score})$$

[FA-2]: Field of Play

To help to focus on the development of software algorithms and unifying the condition for all participant teams, this competition will be held in an indoor area. The playing field is a simulated model of an urban environment consisting of several streets, crossroads, buildings, obstacles and designated places with markers. Figure 2 shows the field of previous competition and a schema of it. The playing field consists of these elements:

1. Starting point
2. Obstacles
3. Emergency Delivery Location
4. Electricity pylons inspections
5. tall building inspection (and package delivery)

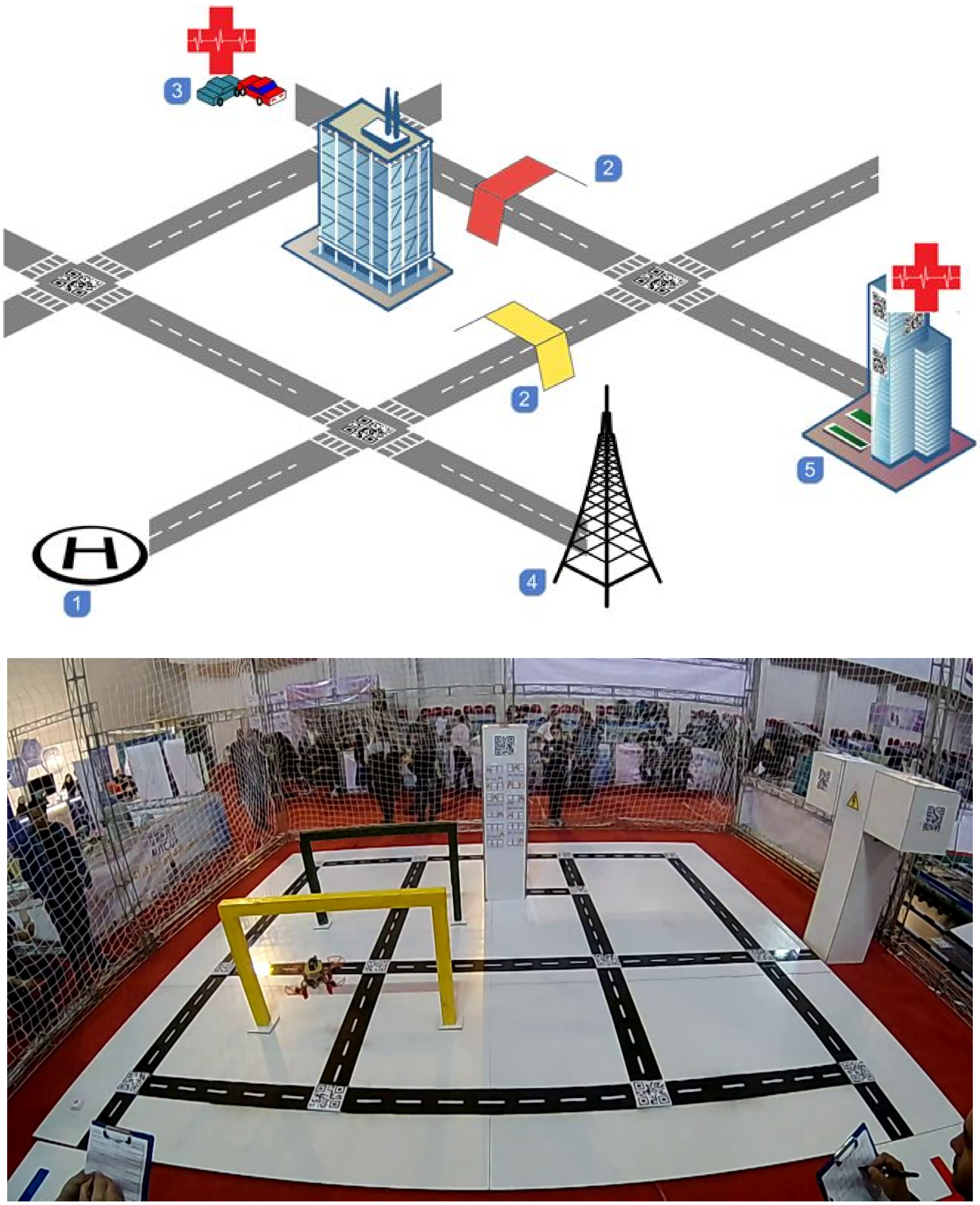


Figure 2, a schema of the playing field.

Streets have a different color to the floor (white or black) and a dashed line in the middle. These roads are connected to each other by several crossroads, and there is a QR code located in the center of each crossing. Data of these QR codes tell the drone where it should go next to reach every mission elements.

[FA-3]: Mission Elements

The overall scenario consists of several mission elements: The drone should deliver a first aid package to a specific location while flies on a predefined path and avoids any collision with obstacles. After delivery, it should go to the tall building and electrical tower for inspection and then return to the starting point and land.

The description of mission elements :

1. **Visual navigation:**The drone should follow the streets to the destination (the next target position). After reaching a crossroad, scanning the QR code (20cm x 20cm) defines the next direction to reach target positions. This mission element is scored if the drone gets from the source (previous target position) to the next target position correctly (following directions in QR code). Every time the drone gets out of the path (over 0.5 m distance to the center of the line) or turns in a wrong direction at crossroads, 1 point will be removed from this mission element score. A more detailed description of QRs and destination is given at the next section of the rules.
   The streets are 20cm wide, with dashed lines (2cm wide) in the middle.
2. **Collision avoidance:** There are several obstacles (in 2 colors) in the environment and drone must identify and avoid them by changing its altitude according to their color. Crossing each detected obstacle without any collision will result in a score.
   The obstacles are colored gates (fig. 3), 1.5 m wide, 1m high and 10cm thick. The color of the gates would be yellow and red. The drone should go through yellow gates and above red gates to get a score of this mission element.
3. **Delivering the first aid kit:** The delivery destination is marked on the ground by a red cross (**Target Position 1**). Drone should either land on the marker or gets in 0.5m altitude, release the package and fly again. The distance between the center of the marker and the place where drone releases the package (point of impact) will define the score of this section.
   The package should be installed on the drone before flying. The weight and size of this package are roughly 80g and 8x8x3 cm with a small hook above it.
4. **Insulator scan in electrical tower:** The drone should identify QR codes installed on the insulator model (fig. 4, 2m high) and report them. This procedure should be done by taking pictures from different angles of the tower. Location of this mission element is considered as **Target Position 2.**
5. **Searching for victims in tall building:** The drone should scan different locations of the tall building to find QR codes and read them to identify victims. Reading QR codes that don't contain any meaningful information about victims will not result in score for this mission element. Location of this mission element is considered as **Target Position 3.**
   The tall building is a cuboid (2m high), and there are several QR codes (20cm x 20cm) located on different sides of it.
6. **Return and land on starting point:** The drone has to follow the path back to the starting point and land on the platform (**Target Position 4**). The landing pad is 1x1 m and is marked by a blue H symbol.

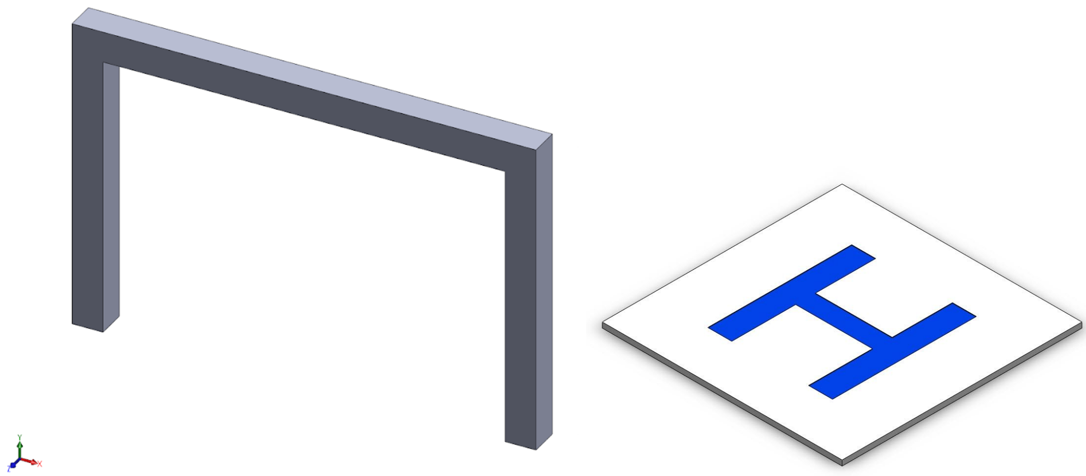


Figure 3, a schema of the obstacles and H pad in the field.

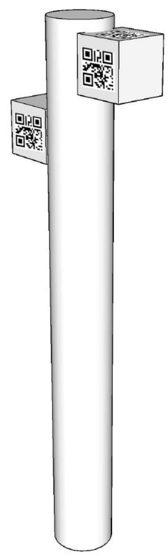


Figure 4, Electricity pylons model.

The following table shows scores of each mission element:

Number	Mission element	Score
1	Navigating to destination	3 points for reaching a destination (to next target position) -1 point for each wrong direction or getting out of path Only navigation from each target position to the next one will be scored. For example starting from target position

		2 and going to the target position 4 would have no scores.
2	Collision avoidance	2 point for each gate (while following the path) -0.5 point for each collision
3	First aid kit delivery	5 points for distance less than 20cm 3 points for distance less than 50cm
4	Insulator scan	2 point for reading each QR code
5	Searching for victims	2 point for reading each QR code that contain victim information
6	Return and land on starting point	2 points for landing on the landing pad -0.5 point for landing anywhere **except** the landing pad

[FA-4]: Details of visual navigation

The QR codes in the crossroads of the field contain a sequence of directions with this format (for example): "N,E,E,S,0". The N,E,W,S characters correlate to the cardinal directions (geographical directions) to reach the target positions. In this example, the 'N' is the direction to the correct path for target position 1, 'E' is the direction to the correct path for target position 2 , 'E' is the direction to the correct path for target position 3 and 'S' direction to the correct path for target position 4. In other words, if the drone follows the direction of the **first character** in the sequence, after several crossroads, it will reach the target position **1** (second character for target position 2 and …).

The last number indicates whether this position is a target position (1,2,3,4) or not (0). If the crossroad is not located at a target location (destination), the last character in the sequence would be 0 (for example "N,W,N,W,0") and if it is located at the end of a path (a target position), the last character would indicate the target location (for example in target position 3 "S,W,N,W,3").

Figure 5, A sample of QR codes containig the directions

In the fig. 6 a simplified example is shown with only 2 target positions (mission 1 and 2). The drone can reach the first target position by flowing the first character in the sequence (red arrow) and following the second character (blue arrow) will guide it to the second target position.

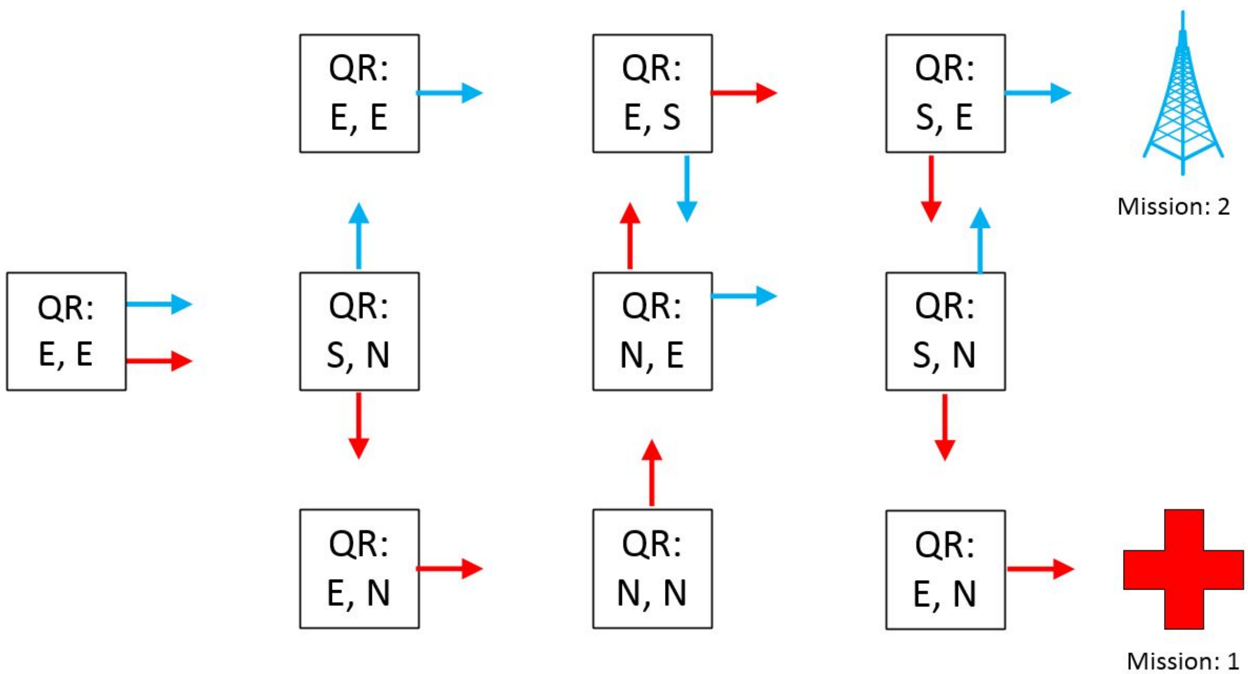


Figure 6, navigation using the QR contents

If the drone turns in a wrong direction at a crossroad (-1 point penalty), following the other QR directions still would guide it to the destination (2 points for following the rest of path).

[FA-5]: Number of Drones

[FA-5.1]: A single drone competes in each mission attempt. Teams are allowed to use different drones for different mission attempts.

[FA-6]: Level of Autonomy

The autonomy consists of 3 levels: teleoperation control (FPV), autonomous control with off-board processing and autonomous control with onboard processing. Based on the level of autonomy of the drone in a mission element, a coefficient is multiplied in the achieved score of that mission element. The coefficients are defined in the following table:

Level of autonomy	**Ka (Coefficient)**	**Comments**
Teleoperation (FPV)	1	Control and navigation of the drone in that mission element is done by an operator without direct line of sight.
Autonomous (off-board Process)	6	Control and navigation of the drone in that mission element is performed autonomously, and some processes are done using a computer outside of the drone itself.
Autonomous (on-board Process)	9	Control and navigation of the drone in that mission element is performed autonomously, and all of the processes are done using a computer inside the drone itself.

NOTE:

- Switching between different level of autonomy is allowed for different mission elements.

For example, the drone can autonomously navigate to target potion 1 and then the operator can switch it to FPV control to deliver the package manually.

- In the manual control (FPV), reading the QR codes for visual navigation (mission element1) is not necessary but this mission element will be scored only if the correct path is traveled.

- If a visual navigation element is skipped or done manually, the starting point of the next mission element in autonomous control should be from 2 crossroads before the target position.

- The participant teams can use their own custom marker for mission elements but a -1 point penalty will be calculated in the score of that mission element (for each marker).

[FA-7]: Method of Scoring

The score of a mission depends on the performance of the drone and the level of autonomy. It will be calculated using the formula below:

$$Mission\ Score = \sum_i (S_i * Ka_i)$$

In this formula, "i" is the mission element number, S_i is the achieved score and Ka_i is the level of autonomy in that mission element.

Example of scoring:

A drone autonomously (offboard) navigate to target position 1 while avoiding 2 obstacles. Then autonomously navigate to target position 2, avoids one obstacle on the path and manually (FPV) scans 4 QR codes. Finally, it starts from target position 3 (the operator manually fly the drone to target position 3) and autonomously navigates to target position 4 and land on the pad.

$$Mission\ Score = \sum_i (S_i * Ka_i)$$
$$= 3*6 + (2+2)*6 + 3*6 + 2*6 + (2+2+2+2)*1 + 3*6 + 2*6 = 110$$

[FA-7]: Technical Challenge

Apart from the main competition, there will be an additional side competition (a technical challenge) for the participant teams. The details of this challenge will be announced on the setup day and during the competition days, the teams should develop a system to overcome this challenge. The main theme of 2019 technical challenge is “Collaboration with a ground robot for navigation”. For this challenge, FIRA Air teams should collaborate with other leagues’ teams such as “warehouse robots league”. The team with the best performance in the technical challenge will be awarded. Scores and award of the technical challenge are completely independent of the main competition.