ICUAS '22 UAV COMPETITION

RULEBOOK, v. 2.0, April 1st, 2022

This document is subject to change, refinement and development.
Changes from the previous version are shown in red.

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Introduction

The new, innovative aspect of ICUAS ’22 is that it will include – for the first time – an Unmanned Aerial Vehicle (UAV) Competition. The Competition is **student-focused**, offering unique opportunities for students to test and compare their skills with those of their peers, worldwide.

The scenario of ICUAS ‘22 UAV Competition is based on challenges faced by fire fighting UAVs in a complex urban environment. This scenario is divided into three sub-challenges that will test the perception capabilities, speed and agility of UAVs.

To facilitate participation and lower the entry barrier, the competition will be divided into two phases:

1. Phase 1 (qualifiers) - simulation: ROS-Gazebo simulation environment that will enable development and testing of your methods remotely.
2. Phase 2 (finals) - live trials at the conference venue in Dubrovnik, Croatia, in an indoor arena set up with a motion capture system.

Both phases will be based on the standardized platform that the organizers will provide for the live trials. Simulation phase kicks off on February 1st, 2022!

IMPORTANT:
Rules for the competition and scenario details are subject to change! Make sure to check the competition website:
http://www.uasconferences.com/2022_icuas/uav-competition/
and this rulebook regularly. All clarifications and FAQs will be publicly announced. All communication regarding clarifications on scenario descriptions, rules and scoring must be via the official competition e-mail: uav-competition@uasconferences.com or via Github discussions: https://github.com/larics/icuas22_competition/discussions.

The final scoring scheme, including time limits and penalties, for the simulation phase will be announced after the first evaluation runs in April.
The scoring scheme for the finals, if changed from the simulation phase, will be announced by the end of the simulation phase (tentative date May 10th, 2022).

Eligibility criteria and team composition

The competition is open to any full-time BSc, MSc and PhD students (a proof of student status will be required by the end of the simulation phase). There is no fee to participate in the simulation phase.

There is no limit for the number of team members for the simulation phase. The number of team members to participate in the finals will be limited for in-person attendance, but other registered team members will be allowed to support the on-site team remotely.

Each team must elect a Team Leader (TL) who will be responsible for communication with the organizing committee and referees. Each team can elect one team advisor who is a member of faculty at one of the universities that the student team members are enrolled in.

Given the dynamic nature of robotics competitions, which usually evolve with participant feedback, teams will be allowed time to find the optimal group of people to tackle the challenges. Final list of teams and their members will be announced after the team documentation is verified.

Competition scenarios: firefighting UAVs

To successfully extinguish a fire, an UAV needs to navigate through an obstacle dense urban environment, localize the fire and deploy a fire extinguishing ball precisely to the localized target area. From a such scenario, three distinct tasks arise:

- Task 1: exploration
- Task 2: target detection
- Task 3: precision delivery

The firefighting capabilities of UAVs will be tested in an arena with three defined zones, as shown in Figure 1.

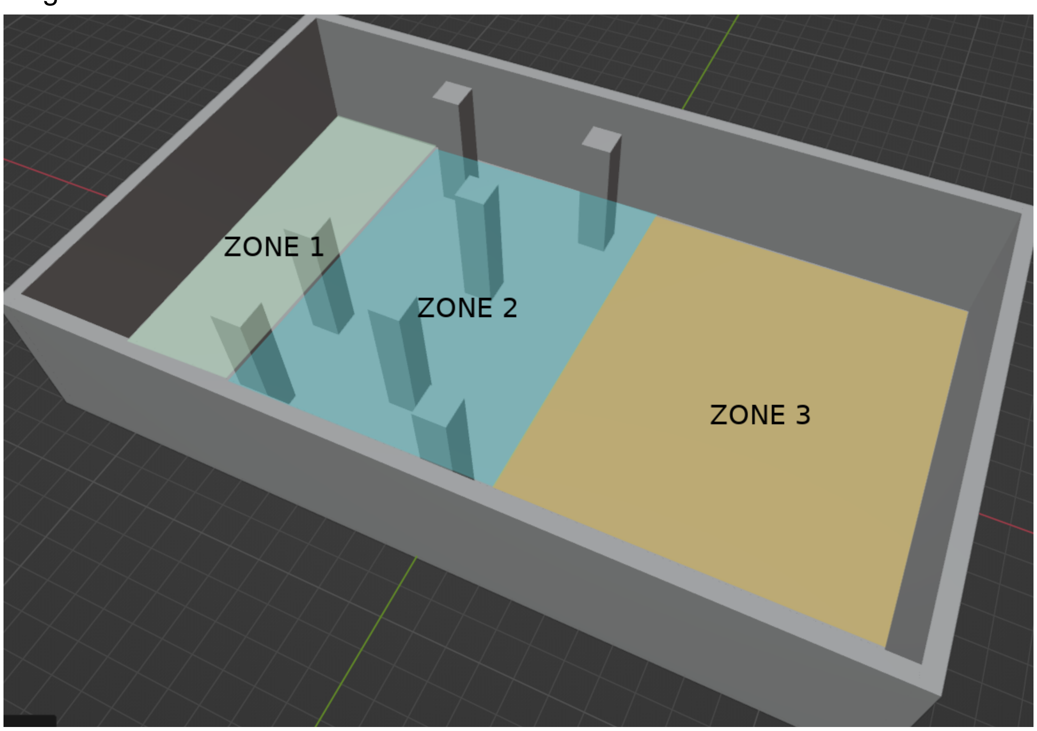

Figure 1. Firefighting scenario arena

Zone 1 (shaded in green color) is the take off zone, and it is clear of obstacles. Zone 2 (shaded in blue color) is the exploration zone and it contains multiple static obstacles, arranged in a way which may result in dead-ends. Zone 3 (shaded in orange color) is the target detection and precision delivery zone, and it is obstacle free. Zones for the simulation phase are defined as follows (all values are in meters):

- Zone1: x = [-12.5,-8], y = [-7.5,7.5], z = [0,4.5]
- Zone2: x = (-8, 1], y = [-7.5,7.5], z = [0,4.5]
- Zone3: x = (1, 12.5], y = [-7.5,7.5], z = [0,4.5]

Task 1: exploration

To complete the exploration task successfully, the UAV needs to navigate from Zone 1 to Zone 3. Teams will be able to select between two levels of difficulty for this task:

- Exploration difficulty level 1: Team will be provided with a map of the arena, including obstacles in Zone 2, and will need to plan a trajectory to reach Zone 3 from Zone 1. The map will be provided as an octomap.
- Exploration difficulty level 2: Team will be provided with bounding boxes of zones 2 and 3 and the UAV will need to find the way through obstacles in Zone 2 to reach Zone 3, mapping Zone 2 along the way. Each run with exploration difficulty level 2 will automatically be ranked higher than any run with difficulty level 1, regardless of point totals.

Task 2: target detection

To complete this task, the UAV will need to search the area of Zone 3 for the target (“fire”) that will be labeled with an AR tag. Once the search in 3D space is completed and the target is found, its 3D position in the global coordinate frame (motion capture frame) will need to be reconstructed. The reconstructed position, corresponding to the center of the tag, will then be evaluated for precision with respect to the calibrated position of the center of the AR tag in the motion capture frame. To signal the successful target detection, the team will be required to publish an annotated image of the target to a predefined (ROS) topic.

Task 3: precision delivery

Finally, once the UAV knows where the target is, it will need to plan a launch trajectory to deliver the fire extinguishing ball to the target. While Zone 3 is obstacle free, the team will need to plan a ballistic trajectory for the fire extinguishing ball, combine it with the motion of the UAV, while ensuring the UAV does not hit the walls or the ceiling of the arena. The performance within this task will be evaluated based on time needed to plan the launch trajectory, time needed to execute the launch trajectory, and the success in hitting the target.

Competition run

One competition run consists of a sequence of all three tasks, which the UAV should perform without stopping, landing, or any manual intervention from the team. During a run, the UAV must be fully autonomous. The run is considered complete once the fire extinguishing ball is released and the ball lands. The UAV does not need to return to Zone 1 to land.

Competition platform

The environment for the simulation phase of the competition is the Gazebo simulator (http://gazebosim.org/), in conjunction with Robot Operating System (ROS, https://www.ros.org/). Being realistic and modular, the combination of Gazebo and ROS enables simulations of both actuators and sensors through various plugins. For the ICUAS ‘22 UAV Competition, the supported versions, and also the versions that the solutions will be evaluated on, are Gazebo 11 and ROS Noetic, running on Linux Ubuntu 20.04 LTS. Teams may opt to use different versions, in which case they assume the risk of their code not running on the evaluation machine. Also, support from the competition organizing committee may be limited if other versions are used.

The simulation platform is modeled after a Kopterworx Eagle platform, as a rigid body with 4 arms, equipped with 4 propellers. To simulate the propeller dynamics, the *rotors_simulator* (http://wiki.ros.org/rotors_simulator) package is used. Inertial Measurement Unit (IMU) and odometry plugins are mounted on the vehicle, to provide the UAV attitude and position. To simulate a depth camera, *openni_kinect* plugin is used. The UAV is controlled through Software-in-the-loop paradigm, using https://github.com/larics/uav_ros_stack. The control stack is packaged into a simulation stack and is available at https://github.com/larics/uav_ros_simulation.

Software-in-the-loop approach enables easier transition from simulation to the real platform, by simulating low level flight controllers. In the simulation phase, the simulation stack runs on Ardupilot, which will also be used on the Pixhawk flight controller in the finals. In addition to Pixhawk, the platform for the finals will carry an Intel NUC computer, connected to the Pixhawk via Mavlink protocol. As already mentioned, both the simulation and real platform are controlled via https://github.com/larics/uav_ros_stack. Installations for both the simulation and real platform stack will be provided via Docker containers after the competition kick-off, along with more detailed technical descriptions of the platforms and algorithms.

UAV dynamics

Other than Universal Robot Description Format (URDF) files, no additional data on the dynamics of the model will be provided by the organizers. Teams will be allowed to identify mathematical model of the simulation platform if they require such information for the purpose of trajectory planning. For the real UAV, identification data will be generated by the organizing committee and provided to the teams that qualify to the finals.

UAV controllers

For the simulation phase of the competition, the teams are allowed to develop their own controllers. For the finals, teams must use the existing controllers on the platform.

Fire extinguishing ball release mechanism

In both simulation and on the real platform, the fire extinguishing ball release mechanism is realized using magnets. In simulation, the *Storm magnet* plugin in Gazebo is used. On the real platform, electromagnets are used and the release is triggered via Arduino nano. All of the mechanisms will be designed, mounted and tested by the organizing committee and the teams will not be allowed to make any hardware modifications to the release mechanism. While in the simulation the release of the ball is instant, on the real platform there may be some time delay in releasing the electromagnets after the command. This delay will be measured by the organizing committee and shared with teams qualified for finals so that it can be incorporated into their trajectory planning.

Code and data structures

For each of the tasks of the competition, it is expected that a team's solution will be in the form of one or more ROS nodes. The developed node(s) will interface with the rest of the system via topics and services. List of topics, services and data types will be disseminated to the teams via the technical documentation accompanying the installation files. Subject to feedback from the teams, the organizing committee is open to revise these interfaces to streamline the integration of code developed by the teams. Teams are allowed to use ROS messages and services based on built-in ROS message types to communicate between nodes.

Competition timeline

January 28th	Initial draft of the rulebook published
February 1st	Competition kickoff, simulation phase starts
April 1st	Simulation scenarios and scoring scheme finalized
April 1st	Evaluations start
April 15th	Deadline to upload team information

May 1st	End of simulation phase, deadline for final solution upload
May 10th	Results of simulation phase announced, finalists announced
June 21st-24th	Finals at the ICUAS ‘22 venue. Before the finals start, the organizing committee is planning a 1-day integration workshop with the aim to familiarize teams with the arena, UAVs, and the competition schedule and procedures

Phase 1: Simulation

Installation files for the simulation phase of the competition, including the model of the UAV and a model of the competition arena will be released to the registered teams at the competition kickoff (February 1st, 2022).

Scoring scheme

In the simulation phase, any run in which there were no disqualifying behaviors, will be scored with respect to the following three criteria:

- Accuracy of the reconstructed position of the target (25 points):
  - Number of points = 25 * exp(-2*err), where err is the Euclidean distance of the reconstructed position from the real position of the target. Number of points will be rounded to the closest half point.
- Accuracy of the ball with respect to the target (35 points):
  - Number of points = 35 * exp(-0.5*dist), where dist is the minimal distance of the ball from the target after the release. Number of points will be rounded to the closest half point.
- Time required to perform a run (40 points):
  - Number of points = 40 * exp(-t/100), where t is the total time elapsed from the start of the run to the ball release. Number of points will be rounded to the closest half point.

Total number of points for a run is a sum of the aforementioned point totals for reconstruction accuracy, aiming accuracy, and time required to finish the challenge, if the run is valid (see Disqualifying behaviors below). In case of ties, time required by the UAV to perform task 1 will be used as a tie breaker. Time limit for the simulation phase will be set after the first evaluation runs.

Disqualifying and penalized behaviors

A run will be disqualified, meaning a team will not receive any points for that run in the following cases:

- The code that the team submitted cannot be run on the evaluation machine

- The UAV crashes at any point during the run
- The run exceeds the time limit for a run
- The ball is released before reaching Zone 3 with the UAV.

Penalties will be awarded in the form of deduction of points in case the UAV touches any of the obstacles in the arena. Deduction points will be announced after the first evaluation runs.

A team will be disqualified from the competition if any malicious code or cheating is detected by the organizers during the evaluation.

Evaluation procedure

Following the finalization of the scoring scheme, the teams will be able to upload their solutions for evaluation. Instructions for the upload are sent to team leaders via email, and announced in the competition repository: https://github.com/larics/icuas22_competition/discussions/39. The code that the team submits will be evaluated by the organizers, and results will be publicly available. The structure of the arena (size of the zones) will be the same as in the example files shared with teams, but the layout and number of the obstacles, UAV take-off spot, and the location of the target may vary. The evaluation will be performed regularly, with rankings and points shown on a public website. Within a single evaluation window, the evaluation arena layout will be the same for all teams. Team's final ranking will be based on the average of 5 best runs from the evaluation period.

Phase 2: Challenge arena at ICUAS22

Five best teams from the simulation phase will qualify for the finals at the ICUAS '22 Conference venue in Dubrovnik, Croatia. More details on the finals will be released by the end of the simulation phase.
Our general idea, provided that the travel conditions improve due to the CoVID-19 pandemic, is to provide a Travel Grant for on-site participation for (a limited number of) team representatives.