ICUAS '23 UAV COMPETITION

RULEBOOK

v. 1.0, January 16th, 2023
This document is subject to change, refinement and development. Changes from the previous version are shown in red.

ICUAS'23 competition is organized by:

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CATEC CENTRO AVANZADO de TECNOLOGÍAS AEROESPACIALES

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https://metricsproject.eu/ https://aerostream.fer.hr/ https://icuas.com/

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Introduction

Following the successful launch of the ICUAS UAV Competition in Dubrovnik in 2022, the competition is back for the second edition at ICUAS'23! The competition is organized by LARICS from University of Zagreb through Aerostream project and CATEC from Seville through Metrics project, with support from ICUAS. Inspired by the scenario of infrastructure inspection, the competition will take place in two stages. In the qualifiers stage, teams will develop their solution in ROS-Gazebo environment, and top teams will qualify for the finals stage at the conference venue.

ICUAS '23 UAV Competition is based on challenges faced by UAVs performing infrastructure inspection in an unknown environment. From this scenario three benchmarks arise that will test the perception capabilities, speed and intelligence of UAVs.

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

1. Phase 1 (qualifiers) - simulation and remote work: the teams will be provided with a ROS-Gazebo simulation environment, rosbags and additional data that will enable development and testing of your methods remotely.
2. Phase 2 (finals) - live trials at the conference venue in Warsaw, Poland, in an indoor arena.

Both phases will be based on the standardized platform that the organizers will provide for the live trials. The first phase of the competition kicks off on January 16th, 2023!

IMPORTANT:
Rules for the competition and scenario details are subject to change! Make sure to check the competition website:
ICUAS'23 UAV Competition web
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/icuas23_competition/discussions.

The final scoring scheme, including time limits and penalties, for the simulation phase will be announced after the first evaluation runs.

The scoring scheme for the finals, if changed from the simulation phase, will be announced by the end of the simulation phase.

Eligibility criteria and team composition

The competition is open to any full-time BSc, MSc and PhD students and others of similar proficiency level. There is no fee to participate in the qualifier phase of the ICUAS ‘23 UAV Competition.

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. 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.

Competition scenarios: UAVs for infrastructure inspection

To perform a successful inspection, an UAV needs to navigate through a dense 3D environment, estimating its pose and avoiding obstacles. Upon reaching points of interest, the UAV needs to scan the area and detect any defects in the infrastructure. These capabilities will be tested in an arena similar to the one shown in Fig. 1.

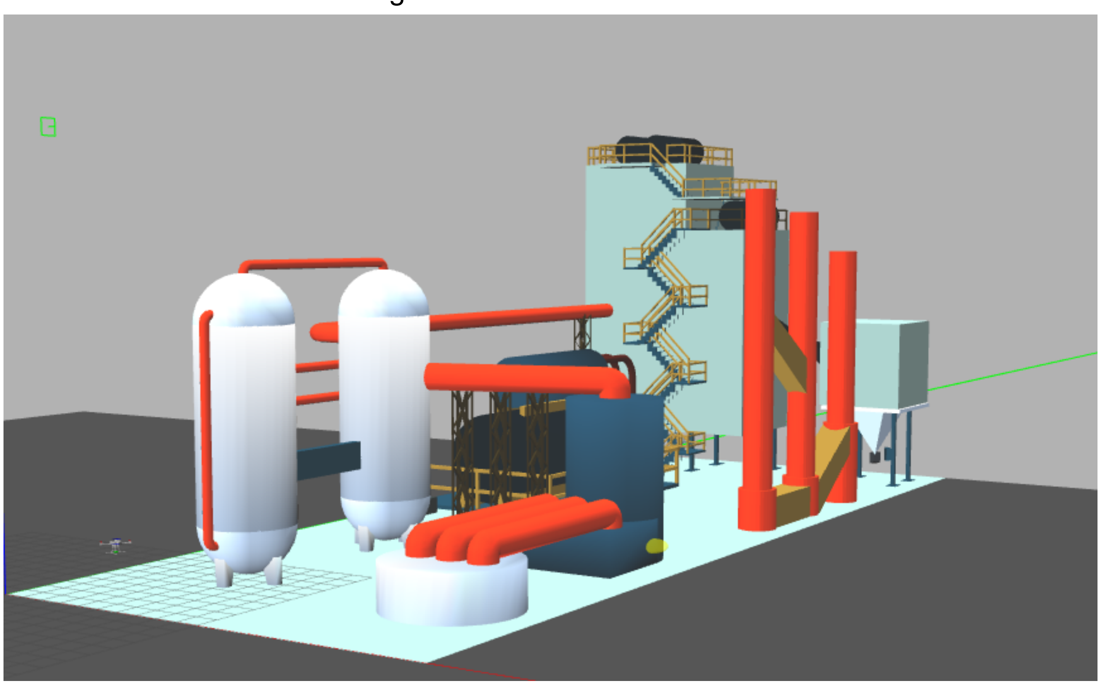

Fig. 1: Competition arena in Gazebo simulation environment

To evaluate the performance of one UAV in such scenario, three benchmarks will be used in ICUAS'23 UAV Competition:

- Benchmark 1: Exploration - The ability to navigate the unknown area safely and to find the defects in the infrastructure. The exploration will be evaluated in a ROS-Gazebo simulation environment
- Benchmark 2: Perception - The ability of the UAV to find, detect and classify defects. Perception will be evaluated on a dataset provided by the organizers.
- Benchmark 3: Pose estimation - The ability of the UAV to estimate its pose in a GNSS denied environment using onboard sensor data. Pose estimation will be evaluated on rosbags provided by the organizers.

Benchmark 1: Exploration

- This benchmark focuses on the ability of the UAV to autonomously navigate unknown areas and find points of interest, scan the area and detect objects of interest. The benchmark will be evaluated both in simulation and in the real scenario. The benchmark allows the teams to explore using various techniques (SLAM, visual odometry, sensor fusion, autonomous exploration) to achieve the desired behavior.
- Benchmark 1 run: one run consists of sequence of actions by the UAV that can be summarized as follows: Take off in take off zone -> visit points of interest -> detect objects of interest -> return to hover in the take off zone. For a run to be valid, the UAV must not crash or contact obstacles at any point during the run and must safely return to the take off zone.

Benchmark 2: Perception

- This benchmark addresses the problem of finding AI methods to detect where a defect is located in a given image, and data handling in order to augment and diversify a small dataset to achieve a good performance in completely new scenarios. The estimated locations of defects in the images are compared with labels manually generated by inspection experts.

Benchmark 3: Pose estimation

- This benchmark addresses the problem of accurately estimating the aerial robot pose (position and orientation) using only data from onboard sensors. The estimated pose is compared with a very accurate motion tracking system from CATEC indoor testbed.

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 '23 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 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. The finals platform will be equipped with a depth camera (Intel Realsense) and IMU. GPS and RTK will not be used. 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 through the competition repository 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 pose estimation. For the real UAV, if necessary, identification data will be generated by the organizing committee and provided to the teams that qualify to the finals.

UAV controllers

The teams are not allowed to develop their own controllers for the UAV. Teams are allowed to develop their trajectory planners that interface with the UAV controllers the same way that the provided trajectory planner does.

Code and data structures

For benchmark 1 of the ICUAS'23 UAV 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. The solution is to be submitted through Docker containers. Exact details will be communicated through the competition repository.

For benchmarks 2 and 3, training data for the benchmark 2 (Metrics FBM2), rosbags for pose estimation (Metrics FBM1), alongside the instructions on how to work with datasets are provided by CATEC and are available for download here (OneDrive/Sharepoint), here (GoogleDrive) or via Docker here. According to Metrics project procedure (check PDF files accompanying the datasets), teams will submit their solutions via Docker files. Base Docker images will be prepared by CATEC and released through the competition repository.

Competition timeline

January 16th	Initial draft of the rulebook published
January 16th	Competition kickoff, simulation phase starts
March 1st	Team registration closed
April 1st	Evaluations start (Tentative)
April 15th	Deadline to upload solutions, evaluations end
April 26th	Results of simulation phase announced, finalists announced
June 6th-9th	Finals at the ICUAS '23 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: Qualifiers

Installation files for the first 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. Data for defect detection and rosbags for pose estimation will also be released to the teams.

Scoring scheme

Total scores for the qualifier phase will be the sum of points achieved in each of the three benchmarks. For a team to score the points, a run in the simulation needs to be valid (i.e. you cannot receive points for perception and pose estimation if the UAV does not perform the inspection task in Benchmark 1).

Benchmark 1 scoring guidelines

The total score for the first benchmark of the competition will be based on the time required to perform the inspection and the number of total defects found. There will be a time limit for this benchmark. The defects in the arena will be from the same dataset as benchmark 2, but only the correct classification will be evaluated. For each defect detected, teams will need to publish an annotated image on a predefined topic. The locations and type of defects will be unknown, but points of interest that the UAV needs to visit will be specified as waypoints. More detailed evaluation of the detection performance will be performed through benchmark 2.

Benchmark 2 scoring guidelines

For each image with an estimated detection, the Intersection over Union (IoU) with the true label is calculated. If this IoU is greater than a given threshold, the detection is a True Positive (TP) and the label is marked as detected. If none of the labels satisfies the IoU criteria, the detection is marked as a False Positive (FP) and no label is marked as detected. Once every detection has been evaluated, the input images are reviewed and every undetected label is marked as False Negative (FN). Then, the Critical Success Index (CSI) is computed as the final result, which stands for the equation:

$$CSI = \frac{TP}{TP+FP+FN}$$

Benchmark 3 scoring guidelines

The provided datasets correspond to three different flights with a gradually increasing level of difficulty in terms of orientation and speed, starting from an easy trajectory without relevant heading changes, then another easy trajectory with heading variations during the flight, and finally a more complex trajectory with heading variations. The scoring will be based on the Root Mean Squared Error (RMSE) of the estimated trajectory with respect to the ground truth trajectory that the aerial robot followed.

Total team score

Teams total score will be the sum of the scores for each benchmark. The scoring scheme, along with the point breakdown for benchmarks will be finalized after team feedback.

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 for benchmark 1 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.

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 will be sent to team leaders via email, and announced in the competition repository. The code/solutions that the team submits will be evaluated by the organizers, and results will be publicly available. The evaluation will be performed weekly, with rankings and points shown on a public website. Within a single evaluation window, the benchmarks will be the same for all teams. Team's final ranking will be based on the average of best runs from the evaluation period.

Phase 2: Challenge arena at ICUAS '23

Five best teams from the simulation phase will qualify for the finals at the ICUAS '23 Conference venue in Warsaw, Poland. More details on the finals, including the possibility of travel grants or similar aid to teams to participate, will be released by the end of the first phase of the competition. Teams can expect setup similar to ICUAS'22 UAV Competition in Dubrovnik, shown in Fig. 2.

Fig. 2: Competition arena in Dubrovnik during ICUAS'22

The Phase 2 of the competition will be conducted in the indoor and separated environment in Warsaw, Poland. This kind of operation is not subject to the current European nor Polish regulations and procedures required from the Civil Aviation Authority of Poland nor the Polish Air Navigation Services Agency.

However in this year's competition, the new regulatory framework element will be introduced to the competition submission and all teams are welcome to introduce themselves to [a brief overview of UAS regulatory framework]. This year's scenario is focused on simulating inspection operations conducted by the UAS. In real life, a UAS pilot/operator could not fly for such purposes without meeting certain requirements regarding licensing, registration and flight coordination. The requirements will depend on location of the flight, including the airspace type, the UAS used to conduct the operation as well as the type of the flight (Visual Line of Sight (VLOS) or Beyond Visual Line of Sight (BVLOS)). In order to bring educational value and educate teams on general applicable regulations and requirements, it will be obligatory for teams to familiarize with material regarding the good practices and types of regulations concerning unmanned aviation operations. The material will also provide the teams with the information of current regulations to be used if the operation was conducted in the outdoor setup. Before being granted license to fly in the competition arena, the teams will need to pass the test. Exact details will be communicated to the finalist teams after the conclusion of phase 1.