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ASUMI: Assuring the Safety of UAVs for Mine Inspection

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Taking humans out of harm's way: using unpiloted aerial vehicles (UAVs) for mine inspection.

Figure 1: Photo Credit: STFC Boulby Underground Lab

Challenge

UAVs are ideal for inspecting infrastructure such as mines. Their use in real-world environments can cause harm to humans, damage the UAV, and damage infrastructure. We need to provide assurance [1] that their use will not cause harm.

Use Case and Safety Assurance

An underground mine is a GPS-deprived environment where a UAV may suffer a failure, e.g., signal loss. The UAV needs to perform a failsafe action (i.e., respond to the failure) to ensure the continued safety of the mine operating domain, the mine workers, mine machinery and the UAV itself. ASUMI developed a testbed and safety case for safety assuring:

- an autonomous return-to-home module for a UAV that enables it to retrace its path and safely return home.

There are three fundamental hazards that the UAV may create during an autonomous return to home failsafe action:

1. Flying too close to an object or surface - the UAV may collide with the object and damage it.
2. The UAV may collide with an object and damage itself (worst case will cause the UAV to crash).
3. The UAV may cause a fire or explosion.

The ASUMI safety case for the return-to-home comprises:

1. Hazard analysis and risk assessment.
2. Deriving and implementing safety requirements.
3. Analysing dependent failures.
4. Verification and validation activities.
5. Confirmation measures for functional safety.

ASUMI used a PX4 Vision Kit UAV in the lab and in simulation to develop the return-to-home system, to provide evidence to justify that it operates safely and that is meets its safety requirements according to the SACE safety guidelines for complex environments (see https://shorturl.at/z7eEo).

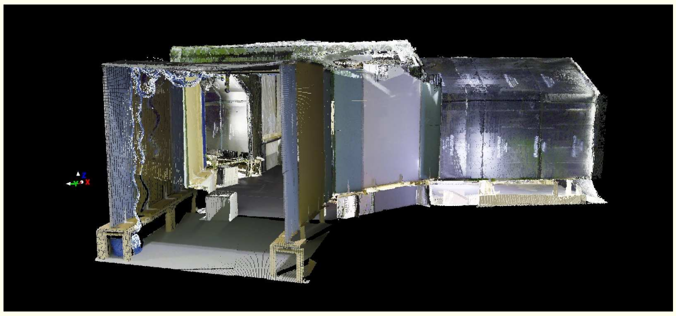
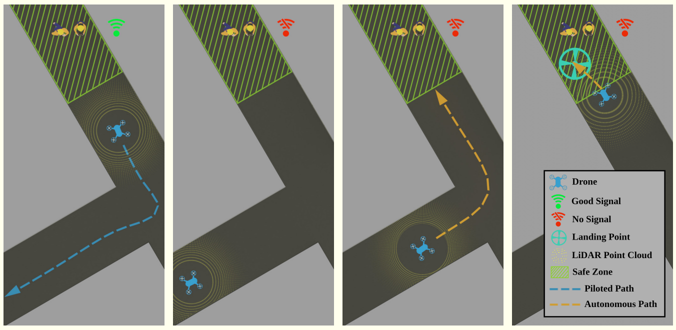


Figure 2: The Aloft mine simulation (from a 3D point cloud).

To provide a mine simulation testbed, we developed Aloft [2] containing a UAV with a self-adaptive controller for a return-to-home scenario. It consists of a Gazebo simulation with two mine models, a modified PX4 Vision UAV model using ROS and PX4-Autopilot for control, and obstacles e.g., humans.



(a) Surveying (b) Signal Loss (c) Return (d) Landing

Figure 3: Illustration of the return-to-home from [2]. The UAV begins to inspect under pilot control (a) but loses signal (b). It must then autonomously return to home (c) and land safely (d).

ASUMI project website:
https://shorturl.at/KpZBM

ALOFT GitHub: Thanks to Calum Imrie for leading on Aloft [2]
https://github.com/uoy-research/Aloft

References

[1] V.J. Hodge, R. Hawkins, and R. Alexander. "Deep reinforcement learning for drone navigation using sensor data". In: *Neural Comput Appl* 33.6 (2021).

[2] C. Imrie et al. "Aloft: Self-Adaptive Drone Controller Testbed". In: *SEAMS'24: Procs 19th Symposium on Software Engineering for Adaptive and Self-Managing Systems*. ACM. 2024.

ASSURING AUTONOMY INTERNATIONAL PROGRAMME

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