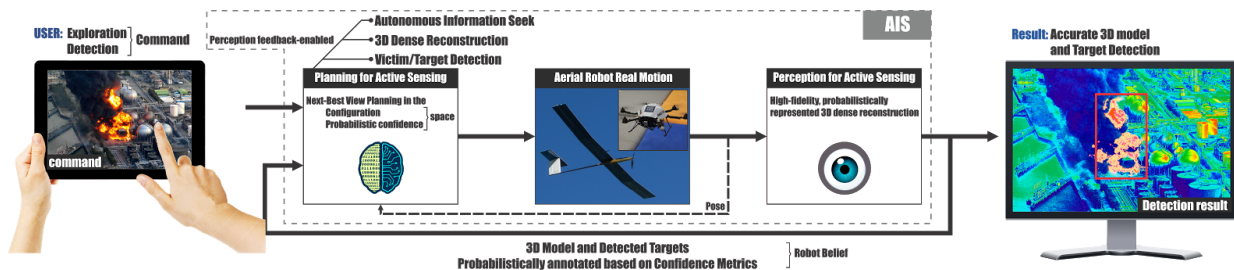


RAS-SIGHT Project:

# Active Information Seeking for Autonomous Aerial Robotic Search and Rescue

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**Project Summary:** This project aims to address the problem of autonomous aerial robotic perception and planning for active information seeking in large-scale, multi-days search and rescue operations. Motivated by the need to assist humanitarian action in major crisis events such as the ongoing refugee waves in the Mediterranean sea, the goal is to equip aerial robots with the navigational and operational autonomy to select viewpoints in real-time such that they perform efficient area exploration -in partially known or completely unknown environments-, by maximizing the expected information gain. Such a novel active sensing capability will lead to the most efficient information seeking for interesting targets in the environment such as human victims, refugee boats or collapsing structures. To reach its goal, the project will achieve a major technological contribution by tightly combining the motion planning loop of the aerial robot with probabilistic mapping feedback of the perception system running real-time 3D reconstruction of its environment, fused with thermal views. A thorough demonstration plan is foreseen to validate, evaluate and benchmark the expected progress in aerial robotic autonomy for search and rescue applications.



**Figure 1:** Envisioned active-sensing approach to autonomous exploration and detection of targets of interest (e.g. human victims)

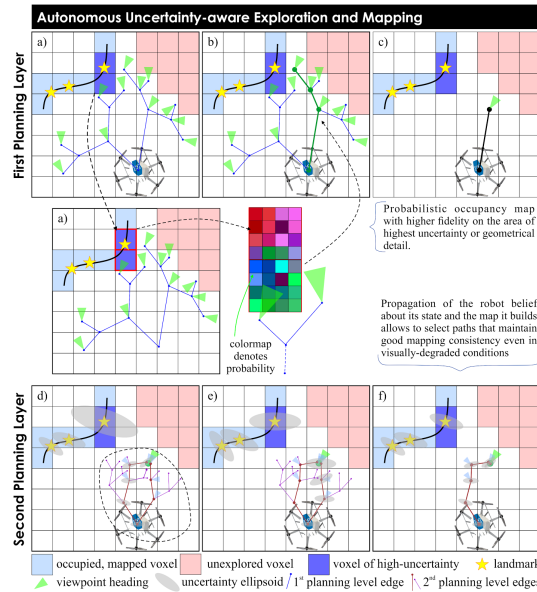
## 1. Summary of Activities

Below we summarize the research activities conducted by our team in relation with this project.

### 1.1. Algorithm Development



Our research team develop an active perception algorithm that ensures that aerial robots can ensure full exploration of a priori unknown environments, subject to localization uncertainty. The relevant algorithm employs a 2-stages process within which it first identifies a finite-horizon sequence of viewpoints that optimizes the expected exploration gain, selects to visit the first relevant viewpoint, while it subsequently identifies the particular way to go there through a trajectory that minimizes the expected localization uncertainty. For the localization model, a visual-inertial odometry pipeline is considered operating in a GPS-denied fashion. The complete operation is iteratively repeated in a receding horizon fashion. Figure 1 presents an overview of how this algorithm operates.



**Figure 2:** 2-step approach on sampling-based receding horizon exploration and mapping

At the same time our team progressed on combining such a path planning approach with multi-modal localization and mapping techniques. The developed methods fuse visual, inertial, as well as depth data. Combining the aforementioned key algorithmical capabilities, we were able to demonstrate autonomous high-resolution, localizability-aware and consistent exploration and mapping of unknown environments.

## 1.2 Experimental Verification

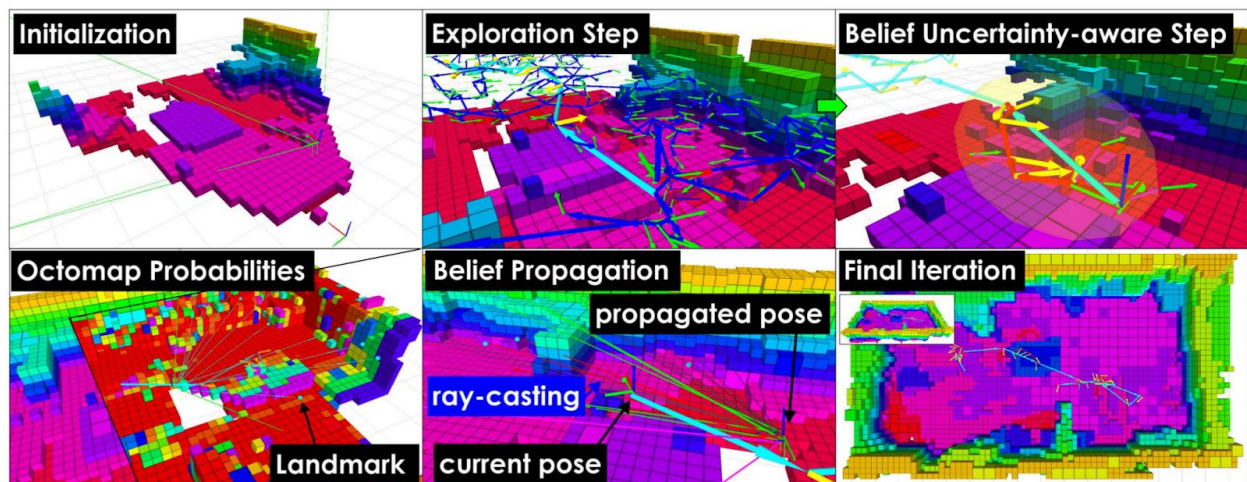
The relevant functionalities were experimentally verified onboard a hexacopter micro aerial vehicle. The relevant system is shown in Figure 3. This system has an arm-to-arm length of 0.45m, weighs 2.6kg, integrates a Pixhawk autopilot responsible for the attitude control functionalities, and utilizes a camera, depth-sensing, inertial measurement unit and thermal camera multi-modal sensor unit, alongside with an Intel i7-based high level processor.





**Figure 3:** The developed aerial robotic system

A set of experimental studies were conducted in relation with a) the autonomous exploration and mapping of unknown environments, b) as well as the detection of humans in such environments. Figure 4 presents instances of one such autonomous aerial robotic exploration of unknown environments employing the relevant active sensing algorithm. A relevant video is available at: <https://youtu.be/iveNtQyUut4>

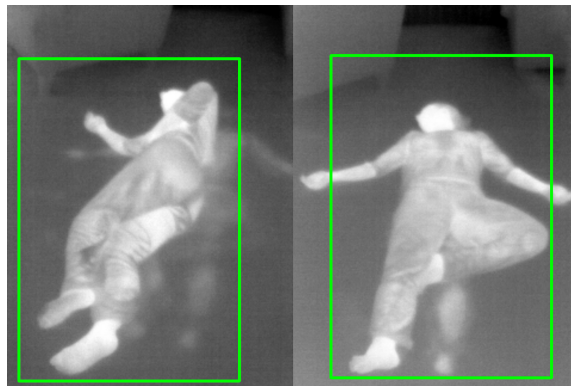


**Figure 4:** Instances of an autonomous exploration and mapping experiment.

This fundamental capability was then combined with victim detection algorithms that operated on the combination of RGB and IR data. Our team implemented the algorithm proposed in the paper: Portmann, Jan, et al. "People detection and tracking from aerial thermal views." Robotics and Automation (ICRA), 2014 IEEE International Conference on. IEEE, 2014. Figure 5 presents indicative results. We believe that this combined skill to explore unknown environments and detect victims



in them in an automated manner is key for the successful utilization of robots in SAR scenarios.



**Figure 5:** Victim detection annotated on the thermal spectrum. A SeekThermal PRO camera is utilized.

## 2. Details on the Project Support

The provided grant supported the aforementioned research and development activities. Table 1 summarizes this support and describes the use of the project funds.

Product	Price	Role in the project
NUC i7 Processor	1500	Main processing unit of the robotic system
ThermalSeek PRO (x2)	1000	Thermal camera of the robotic system

Beyond the financial support for the products listed in Table 1, the project supported our young research team (our lab has 1 year of life) to target specific goals and milestones. The autonomous robotic exploration, mapping and human detection demonstration has been conducted multiple times for university and high-school students. As a result, a significant population of undergraduate researchers, and volunteer high-school enthusiasts participate in our current research objectives. Noteworthy, the complete set of these activities involving aerial robotics target missions of humanitarian benefit, namely: search and rescue, supporting the nuclear site decommissioning efforts, and safety monitoring of open-tip and underground mines. Finally, we are now in the process of exploiting the thermal vision-based detection in the framework of human tracking, leveraging relevant previous work (for indicative result please watch: <https://youtu.be/osmMMnoRT4U>). Last but not least, it is noted that our team has conducted three field test deployments in tunnels and mines.



### 3. Publication Activities

The set of publications mentioned below are related with the project activities:

- [1] C. Papachristos, S. Khattak, K. Alexis, "***Uncertainty-aware Receding Horizon Exploration and Mapping using Aerial Robots***," IEEE International Conference on Robotics and Automation (ICRA), May 29-June 3, 2017, Singapore
- [2] C. Papachristos, K. Alexis, "***Autonomous Detection and Classification of Change using Aerial Robots***," IEEE Aerospace Conference, 2017, Yellowstone Conference Center, Big Sky, Montana, March 4-11, 2017

### 4. Media Coverage

Our relevant lab activities were recently covered by certain media as detailed below:

- [1] Nevada Today, Covering the early steps of the development of the Autonomous Robots at the University of Nevada, Reno, Link
- [2] MIT Technology Review - German Version, Covering the early steps of the development of the Autonomous Robots Link at the University of Nevada, Reno
- [3] Interview at KTVN2 - Face the State for the Research Activities Autonomous Robots at the University of Nevada, Reno, Video

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