ABSTRACT
Unmanned aerial vehicle (UAV) swarms provide situation awareness in tasks such as emergency response, search and rescue, etc. However, most of these scenarios take place in GPS-denied environments, where accurately localizing each UAV is challenging. Heterogeneous UAV swarms, in which only a subset of the drones carry cameras, face the additional challenge of identifying each individual UAV to avoid sending position updates to the wrong drone, thus crashing. This work presents an identification mechanism based on the correlation between motion observed from external camera, and acceleration measured on each UAV’s accelerometer.

1 INTRODUCTION
Unmanned aerial vehicles (UAVs) can provide situation awareness in potential life-threatening scenarios, such as disaster response [6], indoor search and rescue [5], or hazardous substance sensing. In most cases, it is advantageous to utilize multiple UAVs to provide resilience, increase coverage and reduce mission time.

As these scenarios often take place indoors or around debris, where traditional absolute positioning systems such as GPS are unreliable, a common approach is Cooperative Localization [3, 7], in which the UAV swarm shares sensor information to improve their own localization estimation. In particular, vision sensors are commonly used for these purposes [1]. However, a key challenge in these harsh environments is the unstable performance of vision methods due to disturbances from obstacles, varying lighting conditions, etc. As a result, tracking might be interrupted for several seconds before reacquisition. Since the camera information is used to help localize and navigate the drones around the environment, a mistake in the identity of a given UAV might result in crashes. Therefore our goal is to robustly identify drones in real-world scenarios where continuous tracking may not be possible.

A number of prior work approaches can be applied to the UAV domain, including the use of sound, light, radio or vision [2–4, 8], but their performance is limited. Usage of sound (e.g., Doppler effect) to determine the direction of the source is susceptible to the noise generated by the propellers of both transmitting and receiving drones, and results in low accuracy. Blinking an LED with a unique pattern is not robust to bright lights in the background or the presence of fire, a likely event in disaster scenarios. Vision-based person tracking techniques have unreliable accuracy especially for identical flying sensor nodes.

We present a passive vision-based tracking technique that incorporates each drone’s motion information (i.e., Inertial Measurement Unit sensor data) into the tracking algorithm, which is more stable, less vulnerable to varying ambient light, and does not require additional hardware nor communication—such information is already shared in Cooperative Localization systems. Therefore, our contributions are:

- A hybrid UAV identification algorithm which matches visual motion information from an external camera with self-motion information from the IMU.
- An adaptive strategy based on identification confidence that enables a feedback loop to actuate on unidentified drones so they move in known patterns seeking to increase the chances of a higher confidence identification.
- Proof of concept based on real experiment data showing potential for drone identification through our proposed heterogeneous motion sensing matching.

2 SYSTEM OVERVIEW
In our Heterogeneous Cooperative Localization system, a set of worker UAVs are performing the swarm’s assigned task, while one or more spotters use their vision sensors to help localize the workers. However, it is crucial to correctly identify which drone(s) the spotter sees so workers don’t receive incorrect position updates and crash. Figure 1 shows our drone identification mechanism.
The Motion Matching module is thus responsible for estimating the best match $O_i^f \leftrightarrow W_j, \forall i \in \{1, \ldots, L\}$. To achieve this, each object’s $O_i^f$ position is differentiated twice to obtain the visual acceleration $a_{i, \text{spotter}}^f$. The drone identification problem is therefore an injective and non-surjective matching problem between the sets \{$a_{i, \text{spotter}}^f, \forall i \in \{1, \ldots, L\}\}$ and \{$a_{i, \text{on-board}}^f, \forall i \in \{1, \ldots, N\}\}.

3 PRELIMINARY RESULTS

As a proof of concept, Figure 2 shows 40 seconds of experiment data, in which a correlation between a flying worker’s on-board acceleration (red) and the spotter’s visual estimation (blue) can be observed. For each potential match, we evaluate the correlation on a running window and use the result as a confidence metric. When this value exceeds a threshold $t_{\text{match}}^{\text{high}}$ and is $t_{\text{match}}$ times larger than the second best candidate, the worker drone is considered identified. Otherwise, in the event of potential matches with not high enough confidence (but above a threshold $t_{\text{match}}^{\text{low}}$), a command is issued so that unidentified drone(s) oscillate in arbitrary directions, increasing the likelihood of unique correlation.

This technique is also very useful to handle outliers in the Drone Detection block. For example, even if using simple color thresholding to detect drones in the camera image, objects with similar shape and color to a drone would easily be filtered out by our matching and actuation approach.

4 CONCLUSION

This preliminary work presents a novel hybrid and adaptive approach for drone visual identification. Our results show promise for accurate identification based on the correlation between IMU and camera sensed acceleration. Additionally, an actuation feedback loop may be used to disambiguate the identity of low confidence matches faster. The algorithm and strategies explored can also be generalized to broader case scenarios such as wearable device identification in IoT applications or vehicle identification for enhanced security of vehicular networks.

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REFERENCES

