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Wireless Equipment for Localization Using an Unmanned Mini-Helicopter-Based Airborne

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ABSTRACT

It is fully functional and highly portable mini Unmanned Aerial Vehicle (UAV) system, HAWK, for conducting aerial localization. HAWK is a programmable mini helicopter—Draganflyer X6—armed with a wireless sniffer—Nokia N900. We developed custom PI-Control laws to implement a robust waypoint algorithm for the mini helicopter to fly a planned route. A Moore space filling curve is designed as a flight route for HAWK to survey a specific area. A set of theorems were derived to calculate the minimum Moore curve level for sensing all targets in the area with minimum flight distance. With such a flight strategy, we can confine the location of a target of interest to a small hot area. We can recursively apply the Moore curve-based flight route to the hot area for a finegrained localization of a target of interest. We have conducted extensive experiments to validate the feasibility of HAWK.

Introduction

HAWK, which is a programmable mini unmanned helicopter armed with a wireless sniffer and is fully functional for localization tasks. HAWK is a training free and highly portable localization tool and is the first such tool based on an autonomous mini helicopter.

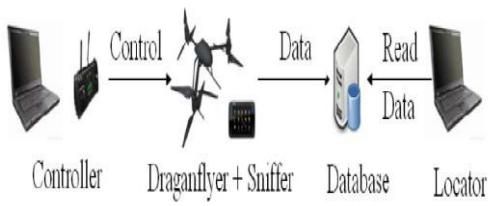
HAWK is a warflying tool. It is more accurate than a warwalking or wardriving tool . Since HAWK can fly to any point in open space, we can set up an airborne Kismet with GPS on HAWK and produce a fine-grained geographical map of wireless access points (APs) or routers.

Wardriving and warwalking are not able to provide such location granularity because it is not possible for cars and not convenient for people to access dead ends such as building roofs.

HAWK can also be used for search, rescue, and surveillance. It is able to sense a target mobile through its wireless signals, either cellular or WiFi. For instance, modern smartphones are often equipped with WiFi devices, which send out probing signals intermittently [3]. When we search and rescue a lost traveler or a survivor from building debris after an earthquake, we can position her by localizing her active smartphones via HAWK flying slowly at a lowaltitude. HAWK can also fly in the vertical plane around a skyscraper to search a suspect hiding in a room and committing attacks via WiFi. The top diameter of HAWK is only 99 cm and its height is 25.4 cm. It can fly both outdoors and indoors and conduct stunts that common large helicopters cannot do.

The most related work to HAWK is W.A.S.P. is also a UAV and has the capability of wayflying. However, W.A.S.P. uses a mini airplane. It has to maintain a relatively high speed and this limits its capability for surveillance because of the cruising speed requirement of locating an active mobile device . In contrast, HAWK can hover statically over a target and has an approximate maximum speed of 50 km/h.

- We built the fully functional HAWK, a mini helicopter—Draganflyer X6 [5]—armed with a smartphone Nokia N900 [6] as the wireless sniffer.
- We designed a Moore space-filling curve-based flight route for HAWK to survey a specific area. To ensure that all target mobile devices are detected during flight, we derived the minimum Moore curve level that is constrained by flight velocity and target packet transmission interval.



Architecture of HAWK.

- Our theorems formally prove that HAWK is more suitable for precise localization than W.A.S.P. because W.A.S.P. has to fly at a minimum speed to float in the air and it cannot take a Moore curvebased route at an arbitrarily large level while HAWK can.
- We conducted both ns2 simulations and real-world experiments to validate the feasibility of HAWK for localization. Our experimental results match our theoretical analysis very well. We were able to achieve a localization accuracy of 5 meters on average.

HAWK in action.

There are five components in this system:

1. **Helicopter.** The mini helicopter we choose for HAWK is Draganflyer X6, a remotely operated, unmanned, and programmable small helicopter designed to carry up to 500-g payload. For HAWK, we mount a wireless sniffer onto X6 to collect wireless traffic.

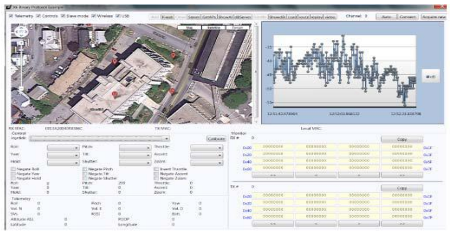


Fig. 4. Setting waypoints on Google map.

2. **Wireless Sniffer**. We convert a smartphone Nokia N900 to a sniffer. This sniffer is attached to a tiltable mounting frame, which was designed for carrying cameras for Draganflyer X6. We choose N900 because its weight is below thepayload limit of the helicopter and it can be easily converted to a wireless sniffer.

3. **Handheld Controller** This joystick controller is the master device controlling the helicopter's landing. It also works as a remedy controller in case a software controller fails.

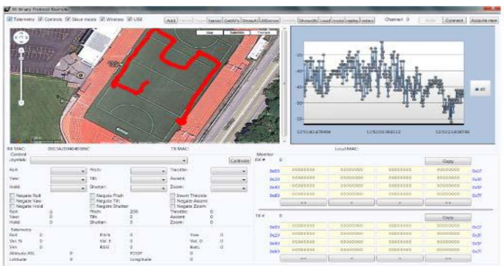


Fig. 5. Displaying flight route in real time.

4. **Software Controller**. The software controller runs on a Lenovo W500 laptop that maneuvers the helicopter flying autonomously along a planned route, and controls takeoff. The software controller can also control landing.

5. **Target Device Locator**. The target device locator runs on a Lenovo W500 laptop. As demonstrated in Fig. 5, this locator can show X6's flight route on Google map in real time and target locations after the surveillance flight. Actually, the function of software controller and target device locator is integrated into one software.

Moore Curve-Based Flight Route

Once the functionality of waypoints is implemented, we can design various flight routes. In this paper, we use Moore space-filling curve to generate a flight route for HAWK. The goal is to ensure that we can fly the shortest distance in a given region while detecting all wireless devices. With a single channel sniffer, we attempt to detect all wireless devices active at that channel. The sniffer can also hop through all the channels to search targets, as does Kismet.

Full-Fledged Localization System

To use the locator to derive the target device's location, we need to transmit the logfiles from sniffer to locator right after the aerial surveillance. Because the wireless card is under monitor mode when Kismet is working, we could not get these logfiles vis WiFi. To resolve the issue, we equip the laptop and the sniffer N900 with the 3G network to download the logfiles from sniffer to locator. However, the 3G network does not provide a public IP address and the locator cannot connect to N900 directly.

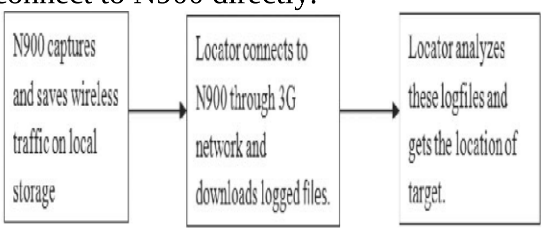


Fig. 6. Localization with full-fledged HAWK.

CONCLUSION

It presented HAWK, a highly portable system for aerial localization of wireless devices in a 3D space. We developed a software controller that utilizes PI-control laws to implement a robust waypoints functionality. For warflying, we generate a Moore curve over the target area as the flight route. To ensure all wireless devices in the area can be detected, we considered the following factors: transmission range of targets, traffic model such as packet interval of targets, flight speed and level of Moore curve, and developed a set of theorems. A minimum Moore curve level is carefully selected so that all wireless devices can be detected at a minimum flight distance. Our theorems ensure that the target device is pinpointed to a small hot area during one fly. A recursive wayflying process over the hot area can refine the accuracy of localization. We conducted extensive ns-2 and real-world experiments. The experimental results match the theorems very well. We are able to achieve a localization accuracy of 5 meters on average.

Our future work includes the study of aerial localization of targets with complicated traffic models and the use of a swarm of UAVs for collaborative localization. For example, three UAVs can work as anchor nodes high above in the sky. They provide a positioning service via laser or sonar to a fourth UAV to locate a target in areas where GPS signals are blocked.

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