Kinetic Controlled Flying of Micro Air Vehicles (MAV) for Public Protection and Disaster Relief (PPDR)

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Abstract: -We present a hands-free kinetic control method for flying of micro air vehicles (MAVs) or small unmanned aerial vehicles (UAVs) for public protection and disaster relief (PPDR). The system combines a 3D depth-sensing camera with a low-cost drone. The solution is based on Delicode Ltd's NI mateTM software toolkit. In a study with 10 participants, the kinetic control method was tested and compared with the drone's normal control mode. The speed to fly a certain path inside a building, and the path accuracy at checkpoints were compared between these two modes. The learning rate with the kinetic control method was found to be better than by normal control. After five attempts, an overall flying speed and path accuracy were still weaker by kinetic control method than by conventional hands-on method. However, hands-free control gives several significant benefits for PPDR applications.

1 Introduction

Public protection and disaster relief (PPDR) responders, such as law enforcement officers, and search and rescue personnel, have diverse needs to acquire information in order to build accurate real-time situational awareness. PPDR responders often find themselves in situations where they would benefit from having "eyes in the sky". Solutions could be provided by small unmanned aerial vehicles (UAVs) or micro air vehicles (MAVs), which would be relatively inexpensive to purchase and operable without long and costly specialized training. These traits would make such services more readily available to a wide range of local civil authorities, such as police, fire and rescue, customs, border control, etc. [8]

1.1 Micro Air Vehicles

The aerodynamics of MAVs is very different from that of conventional, larger aircraft. The Reynolds number, a key component of aircraft design [2], of MAVs are low compared to conventional aircraft (see Figure 1). Because the vast majority of aviation research has been in the flight regime of high Reynolds numbers, designing and operating MAVs present a significant aerospace engineering challenge. More detailed investigation of the unique aerodynamics of MAVs requires further investigation [2]. With different aerodynamics, also controlling of MAVs is different compared to conventional aircrafts.

2 Original Prototype and Earlier Studies

Natural control of MAVs and UAVs is likely to emerge from research in the fusing of several human input and output modalities. The fusion may occur between sensor data retrieved from e.g. eye-, hand-, head- and facial muscle movements [1].

2.1 Parrot AR Drone

AR Drone (see Figure 2) is a radio controlled flying quadrotor helicopter built by the French company Parrot. It is designed to be controlled with iOS devices, such as iPhone, iPad, or iPod Touch, as shown in Figure 3. Today, official apps are also available for Android devices, and unofficial apps for Samsung BADA and Symbian devices [9]. Parrot AR Drone was introduced at the International Consumer Electronics Show (CES) Las Vegas in 2010, and the AR Drone 2.0 was unveiled at CES Las Vegas 2012. This small UAV weighs 420 grams. It features a HD 720P front camera and more sensors such as a
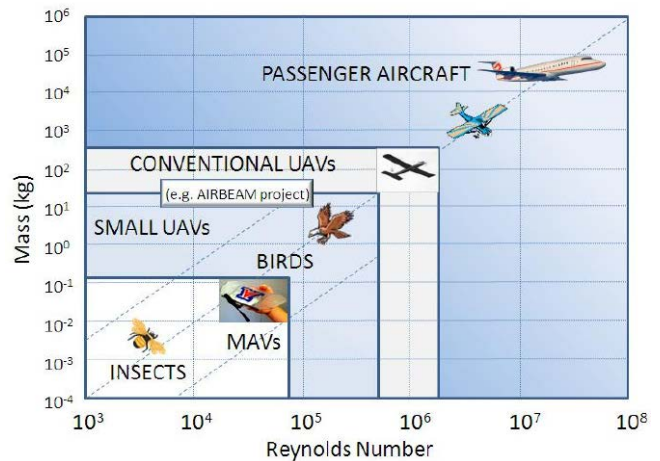

Figure 1. Classes of flying vehicles arranged by mass and characteristic Reynolds Number, adapted from Mueller [5].

pressure sensor working like an altimeter. Communication with the base station is via WiFi. Commands are transmitted to the robot every 100 milliseconds, thus continuously updating the navigation instructions [3].

Figure 3. AR.FreeFligh control application for iPhone [3]

2.2 Demo of Gaze Controlled Flying

Alapetite, Hansen and MacKenzie [1] developed a demo that applies Parrot AR Drone. The intent of the demo was to present a test-of-concept for an "eye in the sky" that can be controlled and manipulated intuitively by gaze. The display in the control room allows the user to perceive visual information acquired by the embedded camera on the drone. Below the display monitor there is a gaze tracking unit. With this, a 'fly-where-you-look' control principle is investigated. Their approach relies on a direct feedback loop with no visible interface components displayed. They utilize the point of regard on the screen directly as the user, who is situated in a control room, observes the streaming video to continuously adjust the locomotion of the UAV.

Figure 2. AR Drone 2.0

3 The Design Process

3.1 3D Depth-sensing Camera together with a Small UAV

Today, cameras can sense depth and track movements. Motion-sensing games are the well-known application of this technology. The 3D depth-sensing cameras are getting smaller and smaller, and we have lately seen the release of many embedded and mobile designs.

One of the additional advantages of 3D depth-sensing is that such a camera, being Infra-Red based, works accurately in the darkness.

Our demo was first introduced at the SNUC 2013 (the Secure communications Network operators and Users' Conference) France on February 26th and 27th, 2013. It is based on Delicode Ltd's NI mateTM software toolkit. Delicore is a start-up company based in Helsinki. It specializes in designing and developing software and user interfaces for these novel sensor technologies. Working together with Cassidian Finland Ltd and Laurea University of Applied Sciences, Delicode designed applications of combining a 3D depth-sensing camera with MAVs.

3.2 Kinect for Windows

Kinect for Windows is a motion sensing input device by Microsoft. It is first developed for the Xbox 360 video game console. Based around a webcam-style add-on peripheral for the Xbox 360 console, it enables users to control and interact with the Xbox 360 without the need to touch a game controller, through a natural user interface using gestures and spoken commands. Today, Kinetic technology is open for several operating systems and the Kinect for Windows sensor and software development kit (SDK) is available. Kinetic sensors and SDK offer a development platform for several end-user experiences. They offer the potential to transform how people interact with computers in multiple industries, including education, healthcare, retail, transportation, and beyond. [4]

3.3 Processing

According to processing.org web pages [7]: "*Processing is an open source programming language and environment for people who want to create images, animations, and interactions. Initially developed to serve as a software sketchbook and to teach fundamentals of computer programming within a visual context, Processing also has evolved into a tool for generating finished professional work. Today, there are tens of thousands of students, artists, designers, researchers, and hobbyists who use Processing for learning, prototyping, and production.*"

3.4 NI Mate

NI (Natural Interaction) mate is a flagship product developed by Delicode Ltd. It is small but powerful software that takes real-time motion capture data from an OpenNI compliant device such as the Kinect for Windows, Asus Xtion or PrimeSense Carmine and turns it into two industry standard protocols: OSC

(Open Sound Control) and MIDI (Musical Instrument Digital Interface). Because NI mate is available for Windows, Mac OS X and Ubuntu Linux, it offers users easy installation and user-friendly configuration interface. Standard protocols for its output make NI mate as a flexible piece of software. NI mate is available for Windows machines through the OpenNI Arena. A new version of NI mate operates e.g. with Kinect for Windows devices. To make the device functioning with NI mate, we installed the Kinect for Windows runtime drivers and SKD from Microsoft. The minimum recommended specifications for a computer running NI mate are a 32 bit (x86) or 64 bit (x64) dual-core 2.66-GHz or faster processor, dedicated USB 2.0 bus and at least 2 GB RAM. The required minimum space for capturing the full armature in NI mate is about 2x4 meters, while the maximum space a sensor device such as the Microsoft Kinect is able to track from is about 3x6 meters. [8]

4 Evaluating the Interaction

Given the above control mechanisms, an evaluation testing of our new control method was carried out. Our goal was to investigate whether the changes of control method result in improved interaction. The kinetic control method was tested as a baseline for comparison against the original hands-on interaction method shown in Figure 3.
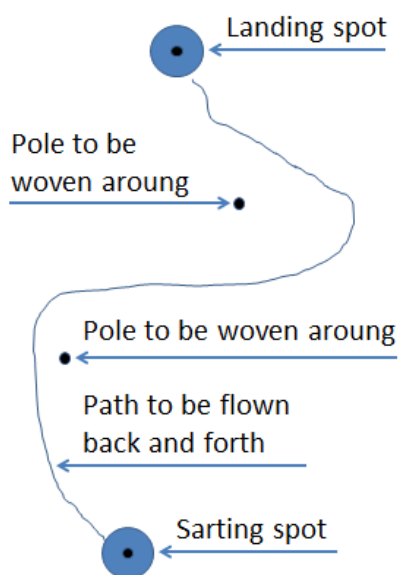
4.1 Participants

Ten unpaid volunteer participants (4 female) were recruited from the local university campus. Participants ranged from 21 to 51 years (mean = 29, SD = 8.8). No one was daily users of MAVs or UAVs. Participants had no prior experience with the system.

4.2 Apparatus

The equipment to be flown was AR Drone 2.0 with 3D depth-sensing camera.

With regard to the hands-on control mode, we applied Apple iPhone 5 64GB multimedia phone with AR.FreeFligh control application.

With regard to the Kinetic control mode, we applied HP ProBook 4545s 15.6" HD/A4-4300M/4 GB/500 GB/Windows 8 Pro 64-bit personal computer, with Kinect for Windows tools and NI mateTM software toolkit.

4.3 Procedure

The experiment was performed in a hall of a university building. Prior to data collection, participants completed a pre-test questionnaire soliciting demographic data. The experiment began with a training session. This involved flying the drone two times from a starting point about 10 meters straight away and then back. This was made by both controlling modes. The goal was to bring participants
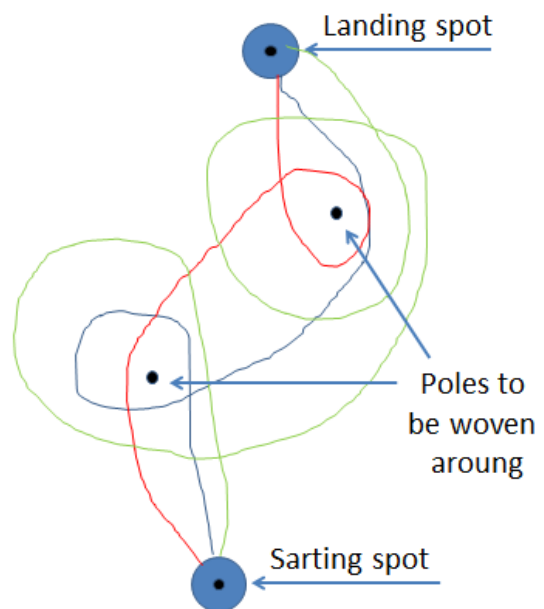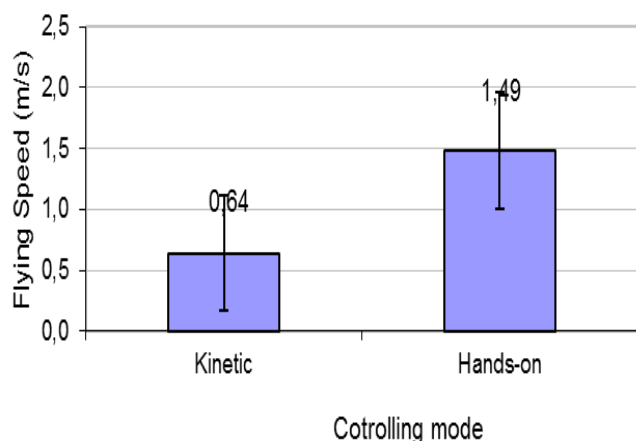

Figure 4. The path to be flown

Figure 5. Alternative paths

Figure 6. Mean rate of flying speed by control mode

Figure 7. Flying speed (m/s) by control mode and trial

up to familiar with flying of drone. Training was followed by flying a certain beforehand marked path five times with both controlling methods. Half of the participants applied kinetic control methods first, another half started with the conventional hands-on method.

Participants were asked to fly "as quickly and accurately as possible" the path, which was marked by tapes on the floor and poles with flags. The 15-metre long path (one direction) started from a marked spot on the floor. After going up in the air, the drone was first flown along with the path to one direction having landing at another marked spot on the floor. Then the drone was flown back via the same path and landed to the starting spot, so the total distance to fly was 30 metre. The accuracy was measured from both landings by the distance from middle of the spot to the nearest point of the drone.

4.4 Design
Figure 4 illustrates the path to be flown. Figure 5 shows the alternative possibilities to fly the path acceptable.

The independent variable is the controlling mode. The dependent variables are flying speed and landing inaccuracy.
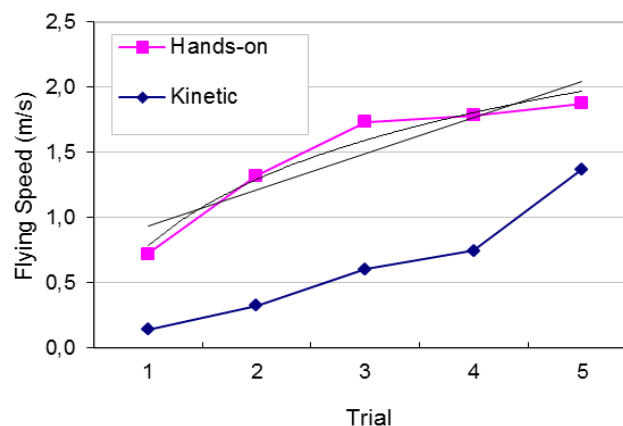
5 Results and Discussion

5.1 Flying Speed
The results for flying speed are shown in Figures 6 and 7. The overall mean rate of flying time was 46.9 sec by kinetic control and 20.1 sec by traditional hands-on control. These values were equivalent to flying speeds 0.64 m/s and 1.49 m/s respectively. As expected, flying speed increased significantly across trials as shown in Figure 7. The learning effect by kinetic controlling method was bigger and it seems that the kinetic control method gains on the flying speed by the hands-on mode after 10 trials, as illustrated in Figure 8. Because the learning effect and low number of trials, the statistical significance of the flying speed with different controlling methods is not able to be tested.

5.2 Landing inaccuracy
Every trial had two landings (one in the middle, another at the end). The results of landing inaccuracy are shown in Figures 9 and 10. The overall inaccuracy was 1.65 metre. The overall mean rate of landing inaccuracy was 2.52 metre by kinetic control and 0.77 metre by traditional hands-on control. This means that the inaccuracy of kinetic control method was 2.9 times worse than by traditional hands-on method. The difference was statically significant ($F_{1,9}=222$, $p<.0001$). However, also the landing accuracy had a great learning effect, as Figure 10 shows.
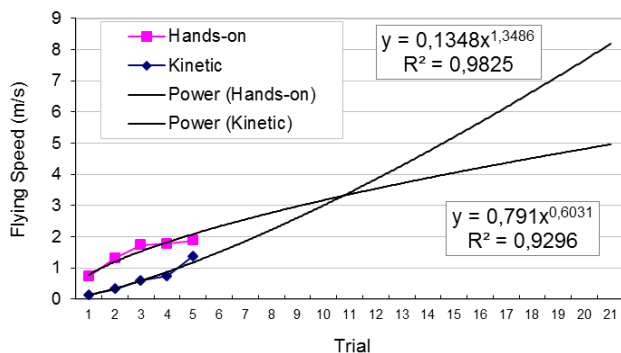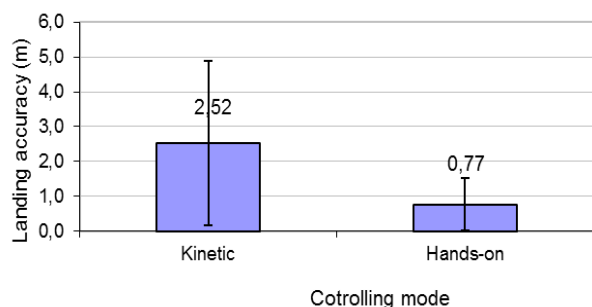
Figure 8. Learning effects

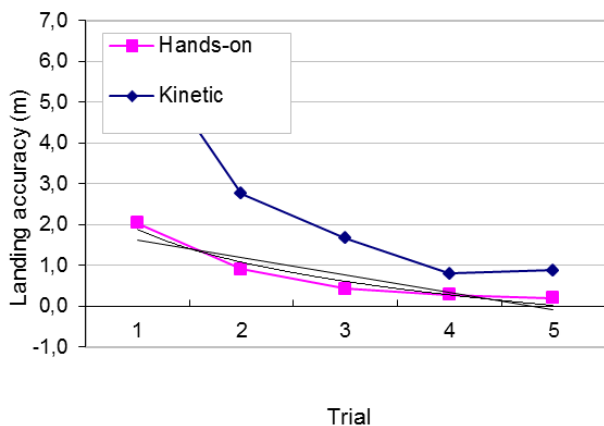Figure 9. Mean rate of landing accuracy by control mode

Figure 10. Landing accuracy by control mode and trial

6 Conclusions

We presented a new kinetic controlling and manipulating method for small unmanned aerial vehicles and micro air vehicles that allows hands-free controlling. In a user study, the overall flying speed and landing accuracy were not so good than by conventional hands-on method. On the other hand, the user study contained only five trials. Because of a significant learning effect, a longer-lasting user study should be arranged.

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