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Poster

An IMU-Based Drone Controller and Its Pilot Evaluation

Z. Cheng[1] and M. Ishihara[2]

[1]Graduate School of Engineering, Fukuoka Institute of Technology, JAPAN
[2] Fukuoka Institute of Technology, JAPAN

Abstract

The rapid advancement of Unmanned Aerial Vehicle technology, particularly the widespread application of quadcopters, has significantly transformed various industries. However, traditional dual-hand controllers like Gamepads impose high complexity and usability demands on users. This study designs and validates an IMU(Inertial Measurement Unit)-based single-hand control system, assessing its practicality and effectiveness through experiments. The results indicate that the proposed controller provides a positive tendency in immersion. Additionally, a quantitative evaluation method for the complexity of drone test courses is proposed and its validity is proved.

CCS Concepts

• ***Human-centered computing*** → ***Usability testing; Gestural input;*** *Laboratory experiments;*

1. Introduction

Drones are widely used in fields like surveillance and photography but often require manual control. Current Gamepad-like controllers can be difficult for many users [MCM12], leading to exploration of natural interfaces like gesture control [LY23]. Additionally, piloting a drone from *First-Person View(FPV)* still remains challenging [Wil06]. There is also a need for standardized evaluation criteria, prompting this study to propose a method for quantifying the difficulty of drone test courses.

This study proposes a finger-based drone controller using finger-worn IMU sensors and reports its performance with pilot user evaluation. A method for quantifying the difficulty of drone test courses is also introduced in this study.

2. Single-Hand Drone Control

2.1. Control Model

Referencing the manipulation of submarines and motor vehicles, the control mode is proposed as shown in Table 1. Specifically, there is no input when the fingers are not on contact.

Table 1: *Control Model*

Touching Finger	Gesture	Drone Movement
Thumb and index finger	Rotate wrist to the left and right	Yaw
	Rotate wrist to the up and down	Throttle
	Pinch strongly	Move forward
Thumb and middle finger	Rotate wrist to the left and right	Roll
	Rotate wrist to the up and down	None
	Pinch strongly	Move backward

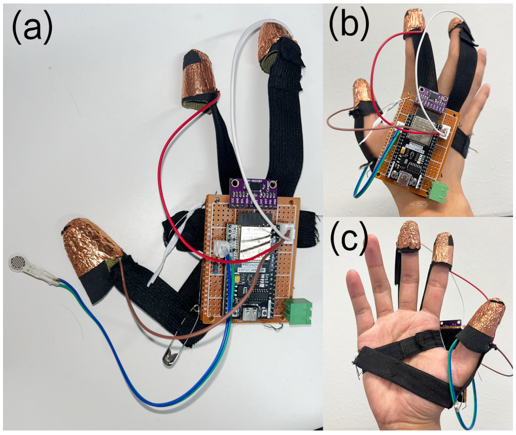

Figure 1: *(a) Controller prototype, (b)(c) Overview.*

2.2. Controller

The proposed controller consists of peripheral sensors and a central controller, as shown in Figure 1. The components are shown in Table 2.

Table 2: *Component Specifications*

Component	Specifications
CPU	Espressif ESP32-WROOM-32E
Attitude Sensor	BNO08X
Film Pressure Sensor	DF9-16, 2×2.5×0.1cm
Copper Foil	thickness 0.05mm
Power	5V-DC

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A piece of copper foil covers on the thumb, index, and middle fingers for conduction and connects to the CPU's IO ports. A film pressure sensor is buried inside the thumb. An attitude sensor detects the hand's three-axis Euler angles. The pressure, fingertip contact status, and posture data are transmitted to the drone using the UDP protocol over a 2.4G WLAN connection.

2.3. Course Difficulty Evaluation

To quantify the course difficulty, after referring the studies [JCL*18, LKYL23], the calculation rule is proposed as follows:

- Along the course, calculate the *number of operations*(*NOO*) (Yaw, Pitch, Roll, and Throttle) between every two successive gates. For example, the the NOO between gates(2)(3) in Figure 2, is calculated as 2(Up/Throttle, Forward/Pitch).
- The NOO for a set of parallel gates is calculated as 1. For example, the gates(6)∼(9) in Figure 2, which are parallel, have a NOO calculated as 1.

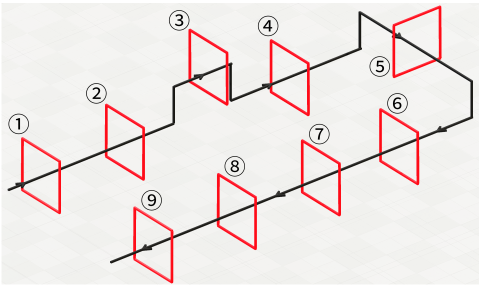

Figure 2: *A course example.*

2.4. Simulator and Courses Set

Unity3D engine is used to build a drone simulator, with a drone model and basic control scripts obtained from the Unity Asset Store. Based on the rules in Section 2.2, four difficulty grades of courses like Figure 2 are set. To ensure that the distance of each course is roughly the same, each course contains 9 gates.

3. Experiment

The experiment involved 24 university students (23 males, 1 female, aged 20 to 27), all right-handed and inexperienced with drones, using the Logicool Gamepad F310 for control. Participants completed two questionnaires: one on *Embodied Cognition (EC)* assessing self-location, body ownership, and agency, and another on *Virtual Experience (VE)* [DVPDM*22] . They were divided into two groups: one using a traditional Gamepad (T) and the other using the proposed natural controller (N), both in a drone simulator. The experiment consisted of four parts: introduction, practice (10 minutes), main experiment (four difficulty levels), completion of the EC questionnaire and the VE questionnaire.

4. Results

Figure 3 shows the movement time and collision count on average for both groups at each difficulty. The movement and collision count for the N group are higher than those for the T group.

Figure 4 shows the questionnaire scores for each group on average. No significant differences are observed (p<.05), but the N group shows a slight advantage in Body-ownership [t(22)=1.42, p=.168] in EC questionnaire.

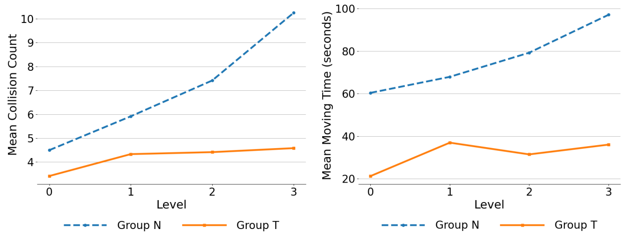

Figure 3: *Mean Collision Count(Left) and Mean Movement Time(Right)*

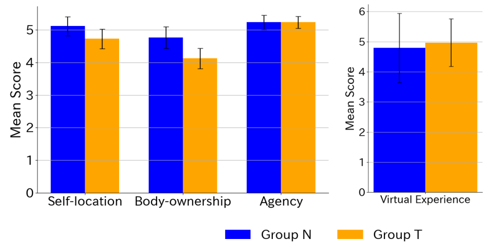

Figure 4: *The score for each group of questions on average in Embodied Cognition questionnaire (Left) and Virtual Experience questionnaire(Right).*

5. Conclusion

This study developed a single-hand drone controller for first-person perspective and tested its usability. A method to quantify test course difficulty was also introduced, leading to the design of four difficulty levels. The results showed the controller improved immersion. However, further refinement of the control mode and drone simulator is needed for a better user experience.

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