IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

A Technical Review on Hand Gestured Controlled Drone

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Abstract- **Unmanned aerial vehicles also known as drones can be controlled using remote controllers, gesture controllers, mobile applications, and embedded computers. In this study we propose Hand gestures as natural method to control drones . We investigate the best way to implement hand gesture via agent-less communication between a drone and its operator. Vision-Based gesture recognition rely on drones camera ability that is image based technique to capture and translate them using model based techniques to meaningful action or information. A set of five gestures are studied.**
In This proposed framework following is also discussed (i) Quadrotor is highly non-linear and fully dynamic coupled comparison was made among different technologies namely Back-stepping, Feedback linearization and Sliding mode control are the three control approaches under nonlinear control. Hence for stable control sliding mode control approaches are suited. (ii) Gentle Ada-boost (GAB) and weighted Linear Discriminant analysis (WLDA) as hand detection technique. (iii) Object detection using AdaBoost algorithm and classifier for better gesture recognition techniques.

1. Introduction

Gesture is a form of non-verbal communication in which message is communicated by visible bodily actions, or in conjugation with speech. Non verbal communication includes the movement of body, arms, hands ,head, or facial expression.
Gesture recognition technology uses these motion of body as an information and that information is made known to the system by mathematical interpretation of
human motion by a computing device.Various types of gesture recognition technologies[4] are- Contact type, Non-Contact, Vision-Based, Electrical Field Sensing. Contact type includes touch based gestures using a touch pad or a touch screen. Non-Contact gesture recognition technology are implemented by device gesture technologies. Device-based techniques

Uses a glove, stylus, or other position tracker, there motion sends a signal which is identified by the system. Vision-Based gesture recognition involves two approaches-model based techniques and image based techniques. In model based technique a three dimensional model of the users hand is used for recognition. In Image based techniques images are captured of the user's motion during course of gesture.
To build a bridge between humans and machines gesture recognition is a way. When an Unmanned aerial vehicle also known as drone is controlled without direct physical contact and it has ability to recognize and interpret movement of human body it is known to be a gestured controlled drone but when only hands are used to express emotions or information to the drone it becomes a hand gestured controlled drone.
A gesture controlled drone can be implemented by using any gesture recognition technology, although Hand Gestured Controlled drone uses mainly device-based techniques and vision-based techniques.
Hand gestures is considered as basic element by most of the current recognition techniques. It is easier to process and analyze it without breaking them into a lower composite element but it leads in rather low-speed inaccurate and fragile performance that is not suited for real time applications. To overcome this problem markers or coloured gloves[16] were used however these techniques are cumbersome for vision based hand tracking and gesture recognition.

2. Hand Gesture Studies

When a drone is being told to move from its current position to another based on the detected motion or gesture of the user using a hand, it is known as hand gesture controlled drone.
There are two approaches for controlling drone through hand gesture :-

- Using specially designed gloves: A controller mounted glove is worn by the user which detects and sends the information to the drone about the movement.
- Using computer vision via on-board camera

The camera is mounted on the drone which detects the user's hand signs and gets instruction of its movements, in other words the mounted camera reads the hand sign of user for the movement.

There are twenty-four basic American Hand Sign Language[7] that have been classified using a boosted cascade of classifiers trained using AdaBoost and informative Haar wavelet features.

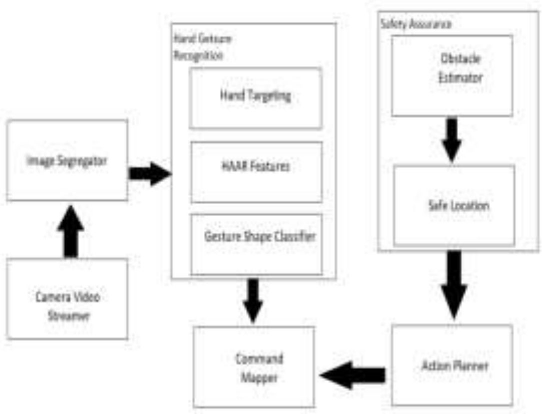

Figure 1. Gesture based drone control framework

AdaBoost at the end of each iteration keeps the track of each weak classifier. Haar features is used for representing each image of data set[6]. Haar cascade has a good detection rate than other feature descriptors and its implementation is simple with more accuracy and consumes less memory.

1.1 Proposed Framework

A sequence of still images or screen shots are extracted from the live video stream from the on-board camera of the drone. Each image then undergoes through the hand gesture recognition process: feature extraction, hand region identification, and finally gesture classification[7]. The detected gestures is then transformed by command mapper into commands like take off, land, or back off. Action planner is responsible for the action or movement of the drone and also ensures safety for the drone by considering the surrounding environment.

There are five set of gestures namely fist, palm, go symbol, v-shaped, and little finger. All the basic functionalities of drone like moving the drone right, left, backward, forward and clicking pictures are covered in the five hand gestures. Three fingers and two fingers gestures are avoided for the gestures as these can be translated into similar Haar features, which may lead to many errors in classification step.

The go symbol, v-shape and little finger gesture are indicated by GS, VS and LF respectively.

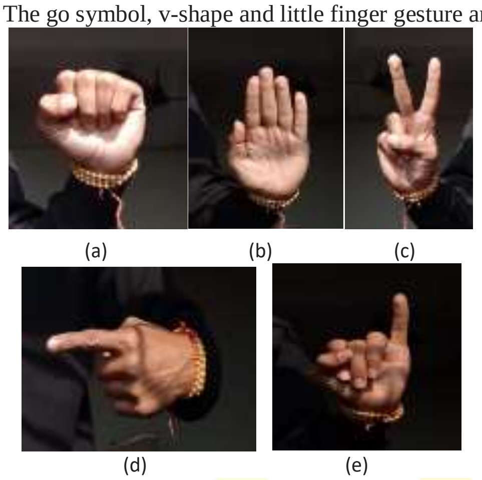

Figure 2. The classification of hand gestures: right hand fist (2a), right hand palm (2b), right hand V-shape (2c), left pointing right hand (2d) and right hand little finger (2e).

For complete framework, there are some challenges that needs to be addressed gesture recognition, safety assurance of maneuver and visual variability of the scene.

3. Comparison of Different Technologies for Controlling the Drone

3.1 Natural Human-Drone Interaction

Wizard-of-oz (woz) elicitation study presents the information about how to naturally interact with flying robots. Natural Interaction need was supported by Human-Robot Interaction (HRI) literature around half a population was agreed they should naturally interact with the drone. When we talk about controlling the drone using embedded computer, according to Jessica R Cauchard[9] there are three ways using gesture ,sound and both. In their experiment using DJI phantom 2 the achieved accuracy in gesture control is 90 percent. While using sound it goes up to 80 percent and when we use both, achieved accuracy is 70 percent. hence, Gesture is proved to be the best way for controlling a drone naturally.

3.2 Different Control Strategies for stable control

Quadrotor has many advantages but it is highly non-linear and fully dynamic coupled. According to Abdellah BenaddY[11] Back-stepping, Feedback linearization , Sliding mode control are the three control approaches under nonlinear control. Using Sliding mode control approach we get a good trajectory tracking with stable system with respect to using feedback linearization and back-stepping. Sliding mode technique consists of bringing the state part of the system to a sliding surface and switching it up to the point of equilibrium[1][9].

the tracking errors of the position and attitude subsystem as follows:-

$$\begin{cases} e_1 = x_1 - x_{1d} \\ e_3 = x_3 - x_{3d} \\ e_5 = x_5 - x_{5d} \end{cases} \qquad \begin{cases} e_7 = x_7 - x_{7d} \\ e_9 = x_9 - x_{9d} \\ e_{11} = x_{11} - x_{11d} \end{cases} \qquad (1)$$

The sliding surfaces and its time derivative are selected as

$$\begin{cases} \sigma_x = \dot{e}_1 + \lambda_1 e_1 \\ \sigma_z = \dot{e}_5 + \lambda_3 e_5 \\ \sigma_\varphi = \dot{e}_7 + \lambda_3 e_7 \\ \sigma_\theta = \dot{e}_7 + \lambda_4 e_9 \\ \sigma_\psi = \dot{e}_{11} + \lambda_5 e_{11} \end{cases} \quad \begin{cases} \dot{\sigma}_x = \dot{e}_2 + \lambda_1 \dot{e}_1 \\ \dot{\sigma}_z = \dot{e}_6 + \lambda_3 \dot{e}_5 \\ \dot{\sigma}_\varphi = \dot{e}_8 + \lambda_4 \dot{e}_7 \\ \dot{\sigma}_\theta = \dot{e}_{10} + \lambda_5 \dot{e}_9 \\ \dot{\sigma}_\psi = \dot{e}_{12} + \lambda_6 \dot{e}_{11} \end{cases} \quad \sigma_y = \dot{e}_3 + \lambda_2 e_3 \quad \dot{\sigma}_y = \dot{e}_4 + \lambda_2 \dot{e}_3 \qquad (2)$$

For the control laws we use the constant speed arrival law:

$$\dot{\sigma} = -k\,\mathrm{sign}(\sigma), \quad k > 0 \qquad (3)$$

Roll command calculation verifying the necessary sliding condition and to guarantee stability in the Lyapunov direction we find :

$$\dot{\sigma}_\varphi = \ddot{e}_7 + \lambda_4 \dot{e}_7 = -k_4 \mathrm{sign}(\sigma_\varphi), \; k_4, \lambda_4 > 0 \qquad (4)$$

with $\dot{e}_7 = \dot{x}_7 - \dot{x}_{7d} = \varphi - \varphi_d$ and the time derivative is $\ddot{e}_7 = \dot{x}_8 - \ddot{x}_{7d} = b_1 x_{10} x_{12} + b_4 x^2_7 + g_1 u_2 - \ddot{\varphi}_d$ from the equation (4) finding $b_1 x_{10} x_{12} + b_4 x^2_7 + g_1 u_2 - \ddot{\varphi}_d + \lambda_4(\varphi - \varphi_d) = -k_4 \mathrm{sign}(\sigma_\varphi)$ The same structure was used to calculate pitch, yaw and the inter loop command in order to extract as

$$v_1 = (-k_1 \mathrm{sign}(\sigma_x) - a_1 x_2 - \lambda_1 \dot{e}_1 + \ddot{x}_d)$$
$$v_2 = (-k_2 \mathrm{sign}(\sigma_y) - a_2 x_4 - \lambda_2 \dot{e}_3 + \ddot{y}_d)$$
$$v_3 = (-k_3 \mathrm{sign}(\sigma_z) - a_3 x_6 - \lambda_3 \dot{e}_5 + \ddot{z}_d)$$
$$u_2 = \frac{1}{g3} (-k_4 \mathrm{sign}(\sigma_4) - b_1 x_{10} x_{12} - b_4 x^2_7 - \lambda_4 \dot{e}_7 + \ddot{\varphi}_d)$$
$$u_3 = \frac{1}{g2} (-k_5 \mathrm{sign}(\sigma_\theta) - b_2 x_8 x_{12} + b_5 x^2_{10} - \lambda_5 \dot{e}_9 + \ddot{\theta}_d)$$
$$u_4 = \frac{1}{g3} (-k_6 \mathrm{sign}(\sigma_\psi) - b_3 x_8 x_{10} - b_6 x^2_{12} - \lambda_6 \dot{e}_{11} + \ddot{\psi}_d) \qquad (5)$$

through MATLAB, a comparison between feedback linearization (FL), backstepping control (BC) and sliding mode control (SMC) has been presented to verify the performance of its controllers.The desired trajectory of the yaw angle and the position ire $\psi_{des} = 0.3$ rad and $[x_d, y_d, z_d] = [5, 5, 5]$m the parameters of the proposed controller are listed in table 1.

Table 1

SMC	Value	BC	Value	FL	Value
K_1,λ_1	9,3.4	c_1,c_2	1,3	k_{11},k_{12}	1.25,2
K_2,λ_2	9,3.4	c_3,c_4	1,3	k_{21},k_{22}	1,1.8
K_3,λ_3	6.5,6	c_5,c_6	1,3	k_{31},k_{32}	6.5,6
K_4,λ_4	55,15	c_7,c_8	10,20	k_{41},k_{42}	20,10
K_5,λ_5	55,15	c_9,c_{10}	10,20	k_{51},k_{52}	20,10
K_6,λ_6	20,25	c_{11},c_{12}	7,20	k_{61},k_{72}	35,9

Hence sliding mode technique is best suited for stable control of quadrotor.

3.3 Hand gesture detection

In a research Gentle AdaBoost (GAB) and Weighted Linear Discriminant analysis(WLDA)[10] and histogram of oriented feature is used. there are two criteria described for selection of threshold, true positive rate (TPR) is set as d_{min}=0.993 maximum false positive rate (FPR) is set as f_{min}=0.3 in every stage. In this strong classifier are generated by using GAB algorithm.for updating the weight WLDA has avery soft way. This approach is for hand detection technique, even in complex background and it is based on Multi class cascade structure.

3.4 Object detection

For object detection and and process images rapidly and with high detection rate there are three key contributors, the use of an integral image increases speed ,a classifier made from Ada boost and a connection of these classifier[3]. Using integral image feature the rectangle feature is simulated at very high speed. After doing that we use a classifier which remove some background object which we use as a cascade connection of classifier with increasing modularity and detection feature.
here we use a simple feature which is a reminiscent of haar basis function and it is used by Papageorgiou et al.

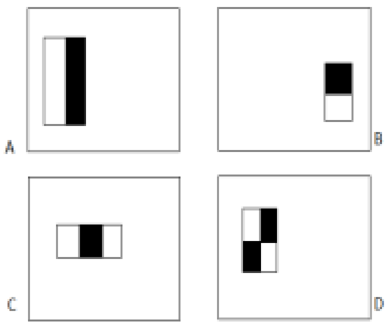

Figure 3. Example rectangle features show relative to the enclosing detection window. (A) and (B) shows Two-rectangle features. Figure (C) shows a three-rectangle feature and (D) a four rectangle feature.

in above figure sum of the pixels which lie within the white rectangles are subtracted from the sum of pixels in the black rectangles. This is the rectangle feature.

We use an integral image for computes rectangular feature rapidly.
The integral image at location x, y contains
the sum of the pixels above and to the left of *x*, y, inclusive:

$ii(x,y) = \Sigma\, i(x',y')$,
$x' <= x,\ y'<=y$

where $ii(x, y)$ is the integral image and $i(x, y)$ is the original image. Using the following pair of recurrences:

$S(x,y) = s(x,y-1) + i(x,y)$ (1)

$ii(x, y) = ii(x-1, y) + s(x, y)$ (2)

(where $s(x, y)$ is the cumulative row sum, $s(x, -1) = 0$,
and $ii(-1, y) = 0$) the integral image can be computed in one pass over the original image.

We can get sum in four reference by using the integral image feature.two rectangle feature in 6 references and three rectangle feature in 8 references.

Weak learning algorithm designed to select single rectangle feature which is better in separate positive and negative example . A weak classifier h_j (x) thus consists of a feature f_j, a threshold 0, and a polarity p_j indicating the direction of the inequality sign:

$$h_j(x)=\begin{cases}1 & \text{if } P_jF_j(x)<P_j0_j\\ 0 & \text{otherwise}\end{cases}$$

Now for boost the classification performance of single algorithm we use Adaboost learning algorithm .The Adaboost algorithm for classifier learning. Each Round of boosting selects one feature from the 180,000 potential features.

- Given example images $(x_1, y_1)\ldots(x_n, y_n)$ where $y_i = 0, 1$ for negative and positive examples respectively.
- Initialize weights $w_{1,I}=\frac{1}{2m},\frac{1}{2l}$ for $y_i = 0,1$ respectively, where m and l are the number of negatives and positive respectively.
- For t = 1, ..., T:
  1. Normalize the weights.
     $$W_{t,i} \leftarrow \frac{w_{t,i}}{\sum_{j=1}^{n} w_{t,j}}$$
     So that w_t is a probability distribution.
  2. For each feature, j, train a classifier h_j which is restricted to using a single feature. The error is evaluated with respect to w_t, $e_j = \sum_i w_i\,|h_j(x_i)\text{-}y_i|$
  3. Choose the classifier, h_t, with the lowest error e_t.
  4. Update the weights
- The final strong classier is:
  $$h(x) = \begin{cases}1 & \sum_{t=1}^{T}\alpha_t\ h_t(x) >= \frac{1}{2}\sum_{t=1}^{T}\alpha_t\\ 0 & \text{otherwise}\end{cases}$$
  Where $\alpha_t = log\frac{1}{\beta_t}$

After that we use a cascade connection of these classifier and we detect object successfully.
From this method a face detection system is generated which is much faster.

4. Results And Discussion

The hand gesture drone involves a MPU6050 and an antenna module of CT6B with two cell power supply and an Arduino nano which involve 2 potentiometer including throttle and yaw

The movement sensitivity is done by MPU6050 gyro which senses the tilt and according to the degree of tilt the pitch and roll is provided to the drone.

The potentiometer helps to provide the throttle and yaw to the drone. It also helps to arm the drone by moving the drone stick to lowest right on the potentiometer.

As a result of the design and construction of the hand gesture drone, the following were achieved:

- The QUADCOPTER was designed and constructed successfully with all its connections.
- The autopilot unit of the autonomous quadcopter was implemented successfully in more than 10 flightsThe HGSAD was able to have a flight of up to 10 mins when fully charged.

4.1. Flight Control System

The flight control system was implemented up to the level of manual remote control. The autonomous system was implemented. However, it was relatively stable and worked as expected. Issues that occurred during testing are discussed below:

4.1.1. Orientation of the SAD

The SAD is orientated thus:
The front of the SAD is such that the RF module faces front and is in the middle of two arms. Counting clockwise from one, from the motor at the right of the RF module, the motors are numbered up to four.

4.1.2. Tuning the gains of the HGSAD

The gains were tested with the propellers rotating at velocity close to what would make it lift off. The response of the HGSAD to the external changes in orientation were manually tested and the gains were modified when there were instabilities present. The flight control code of the HGSAD was upgraded with the new values and the code was uploaded into the flight controller. Further tests were carried and new values for the gains were assumed after manual testing These values were uploaded into the flight controller and further tests were carried out. This process kept on going on until the HGSAD response to external influences on its orientation was adequate.

Upon testing we noticed that a motor was too tightly fixed. This caused the propellers to not rotate freely and also to come to an abrupt stop on some occasions too. This issue was resolved by loosening the screws until free rotation was permissible.

5. Conclusion

Gesture makes it easy for natural interaction between human and flying robot. Hand gesture based technology with maximum possible accuracy is based on different parameters like better interaction, stable control, better detection and classification of hand gestures best suited for hand recognition technology. flight control system is implemented up to the level of semi hand gestures control. The drone movement pitch and roll are controlled by the hand and throttle and yaw are controlled by modified controller. Hand gestured controlled drone is implemented with flight time of 10 minute with fully battery charged.

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