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Unmanned Aerial Vehicle Movement Trajectory Detection in Open Environment

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Abstract

Unmanned aerial vehicles have become more widely used for entertainment, security, building inspection and for other similar tasks. Inertial Navigations Systems (INS) is one of the main area of research for UAVs to control their flights through buildings or near constructions where flight paths must be controlled or recorded. In this paper is collected some approaches, which can be used for UAV onboard trajectory determination where GPS cannot be used are determined. Approach includes onboard inertial measurement unit system and image sensors. Fusing UAVs controlling methods and computer vision gives possibility to increase inertial navigation system accuracy. To determine distance to obstacles dual vision cameras must be used.

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Keywords: Flight trajectory; Unmanned aerial vehicle; Optical flow; Stereo vision; Inertial navigation system

1. Introduction

During the past years, unmanned aerial vehicles (UAV) or drones as some call them have become as major focuses of active researches. Beside mobile robots and UAV have extended possibilities over obstacle avoidance and that is the reason for their various usage applications, such as search-and-rescue, building inspection[1] and seeking. Unmanned aerial vehicles tend to fly over open sky, but even there can occur various obstacles like birds, radio antennas and tree branches.

Flying through building or under tree branches, Global Positioning System (GPS) will not give accurate coordinates because of surrounding environment and obstacle physical characteristics. Taking inspiration from bugs,

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especially form flies, bees and dragonflies, in this paper methods for UAVs inertial navigation and image sensors, which are used for obstacle, rotation and speed detection is collected. Biological researchers turned out, that insects are mainly relying on monocular vision and their possibilities to sense air flow to fly avoiding static and dynamic obstacles[2].

UAVs are controlled by fusing various sensor data (Inertial Measurement Units - IMU) with special algorithms. IMU can provide information only about drone attitude according to earth frame. Knowledge of environment can be gained also using image sensors, using GPS, speed sensors, height sensors etc. Image sensors give possibility to detect obstacles, recognize them and provide information about obstacle dimensions and distance to them. Knowing also UAV flight speed, height and trajectory it is possible to make decision by avoiding collision with detected obstacles.

Many similar sensors, as insects are using, are available as small, light and low power microelectromechanical systems (MEMS). Using two image sensors and some MEMS sensors like three axis gyro rate sensors, three axis acceleration sensors and additionally three axis magnetic field sensors is possible to achieve dynamic flight in the space of various obstacles rather than using bulky 3D scanners weighting more than one kilogram.

In this paper, is given methods and systems, to find drone flight trajectory and speed using IMU and dual vision. From dual vision obtained information about obstacle position can be used for speed and height calculations and for obstacle avoidance methods. There exist methods for calculating flight trajectory over time. Some methods are using GPS and Kalman filters to fuse IMU and GPS data and give in output traveled distance and direction over time[3–5]. The main disadvantage is usage of GPS, because GPS can work properly only in opened vicinity or flying over buildings. Another method uses static cameras and beacons on drones to find their flight path and speed. The disadvantage to this method is bounded space, where drone speed and trajectory can be detected.

2. Inertial navigation system

Inertial Navigation System as input data takes drone inertial sensor measurements, especially linear acceleration sensor and angular rate sensor measurements. Both sensors combination creates inertial measurement unit (IMU). First off all from IMU readings is calculated attitude and in parallel from linear acceleration sensor readings $\boldsymbol{a}_g$ is removed gravity vector $\boldsymbol{G}$ to give clear acceleration vector (see formula (3)). Rotation matrix C is used for attitude and speed vector transformation from global frame $\boldsymbol{v}_g$ to body frame $\boldsymbol{v}_b$ (formula (2)) with subscripts g and b accordingly. Formula (1) shows rotation matrix C which is given in form of quaternion's $q = [q_w \quad q_x \quad q_y \quad q_z]^T$:

$$C = \begin{bmatrix} q_w^2 + q_x^2 - q_y^2 - q_z^2 & 2(q_x q_y - q_w q_z) & 2(q_x q_z + q_w q_y) \\ 2(q_x q_y + q_w q_z) & q_w^2 - q_x^2 + q_y^2 - q_z^2 & 2(q_y q_z - q_w q_x) \\ 2(q_x q_z - q_w q_y) & 2(q_y q_z + q_w q_x) & q_w^2 - q_x^2 - q_y^2 + q_z^2 \end{bmatrix} \quad (1)$$

$$\boldsymbol{v}_g = C\boldsymbol{v}_b, \qquad \boldsymbol{v}_b = C^T\boldsymbol{v}_g \quad (2)$$

Attitude and acceleration vector $\boldsymbol{a}_g = [a_x \quad a_y \quad a_z]^T$ is integrated to find movement speed vector $\boldsymbol{V}_g(t)$ and then speed vector again is integrated to find position $P_g(t)$ on the global frame:

$$\boldsymbol{v}_g(t) = \boldsymbol{v}_g(0) + \int_0^t \boldsymbol{a}_g(t) - \boldsymbol{G}dt \quad (3)$$

$$P_g(t) = P_g(0) + \int_0^t \boldsymbol{v}_g(t)dt \quad (4)$$

where $\boldsymbol{v}_g(t)$ is drone flight speed at time t, $P_g(t)$ is drone's displacement at time t and $\boldsymbol{G} = [0 \quad 0 \quad 9.81]^T$ is gravity vector. Accelerometer and gyroscope readings includes bias error as well. These errors are accumulated by time, especially accelerometer bias error gets integrated two times and it becomes to quadratic error in position calculations. It is possible to reduce the error considering another positioning system. A lot of researches were conducted using GPS to reduce the INS output errors[3–5].