**Navigation of Multi-Copter by Leading the Target Value with Microsoft Kinect**

PROPOSAL

Submitted to Engineering Department

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**Abstract**

Classic Proportional-Integral-Derivative (PID) controller was developed mid-20th century and is being applied for complicated and tedious attitude control of commercial Unmanned Aerial Systems (UAS) or multi-copter due to its accuracy and simplicity of implementation. Recently, with advance of commercial visual motion sensor, Microsoft Kinect, PID controller can extend its application; PID controller directly interacts with human motion without radio-control signal. PID controller targets a desired value set by a pilot signal. It is possible that Kinect replace the signal and lead the desired value for the controller as it senses the motion.

This study is to perform basic rectilinear navigation of the multi-copter based on sensor values. The drone performs linear movement as the object’s coordinate changes to maintain its distance to the target or to execute the command that the change of the object’s coordinate means. For the integrity of the system, a Micro Controller Unit (MCU) and a c# software cooperate. The c# software interprets visual data to coordinate data. MCU receives data and update the target value of PID to modify the drone’s attitude so that it can translate to the corresponding location.

The result of this study will show that the system can stably read the attitude and coordinate data to feedback PID control loop. Based on the PID loop, the system can navigate and maintain its location with simple motion such as linear retreat, advance, descend, ascend, left, right, and yaw.

**Introduction**

UAS are playing an important role in this century due to its versatile functions that conduct various tasks. Remote-controlled multi-copters become the mainstream among, not only general public such as professional photographers, but also marketing-logistics companies such as Amazon Prime Air who recently submitted a petition to U.S Federal Aviation Administration for their R&D

Numerous types of commercial UAS are flourishing. A multi-copter is the most popular type of UAS. However, learning to fly a Remote-Controlled (RC) multi-copter or a RC drone is not intuitive process though the needs of drone keep increasing from various industries. For instance, gained acceleration or momentum of drone can confuse untrained pilot to expect the drone’s possible movement; to deal with such motion of heavy drone, pilot needs great amounts of time to train. Also, the professional missions of recue or military task, RC pilots are expected to be expert at the mission as well as piloting. However, because the human pilot cannot operate multi task while one is piloting, a certain level of autonomy is imperative for UAS.

For better autonomy, remote-controller is cumbersome device for professional purpose such as rescue mission. Since such missions require fast reaction and clear communication, human pilot’s performance may deter the quality of the mission. Thanks to Artificial Intelligence (AI) technology, especially computer vision that can recognize human motion, it is possible for human to directly interact with systems so that computers can interact with humans in an intuitive way. With such intelligence, the systems have manifold potential applications.

- Military: Cooperating and conducting mission with field soldiers.

- Construction: Carrying and placing heavy materials without a crane and cooperating

with human workers.

- Logistics: Delivering packages; or carrying boxes for to move residence to another.

- Rescue: Cooperation with rescuers.

- Hobby: not only mere flying it, but also playing sports such as tennis.

Such robotic systems are primarily composed of three sub-systems, sensing, actuating, and reasoning. Specifically, this paper is mostly about sensor fusion and simple reasoning. Environment of the system is assumed to be cubic indoor place where has less solar rays which blocks motion sensor’s infrared rays.

**Objective**

This study seeks the very basis of such autonomy to move on complicated performance. Linear motions can be a step stone of UAS autonomy since it proves that UAS can recognize an object and understand human motion as well as convey such inputs into actual navigation. The primary objects have 3 aspects: sensor fusion, Kinect software, and PID control loop.

In order to feedback reliable attitude data to PID loop, stable values of current attitude should be fed. Accelerometer data are noisy while gyroscope data are comparatively stable but inaccurate. Given that accelerometer tells angular position and gyroscope tells time rate of change of angular position, those two data can numerically integrated to generate accurate and stable angular position during vibrations due to propellers. To acquire an object’s coordinate, Kinect software should interpret the raw data. Also, the interpreted data such as coordinate or velocity of drone are fed to MCU so PID controller follow its target value. PID controller calculate proper output value for controlling the motor. The constants, are found experimentally. Also, PID controller’s target value or desired attitude are updated by Kinect.

**Methodology**

To accomplish the objectives stated above, there are 5 sub-phases to complete.

Phase 1) Physical Assembly of Drone and Testing Device

A prototype drone is built. The prototype is consist of drone frame, brushless AC motors, electric speed controller, MCU as an autopilot, and a power supply. To investigate the motors’ operating range of Pulse Width Modulation (PWM), Parallax Propeller chip, the MCU is used. Since the MCU has an ability to execute 8 multiple tasks simultaneously, it can run motors while it is reporting the motor data via USB. As increasing PWM, operation range of the motors can be experimentally found.

Phase 2) Ground Station Application

To monitor MCU which does not have an operating system, it is necessary to develop a monitoring application that receives data from MCU via USB and collects data into excel documentation. Since large portion of the application can be re-used for Kinect software, Microsoft Visual C# is selected as a programming language.

Phase 3) Attitude Sensor Fusion

MPU6050 is used for attitude sensor. MPU6050 has two angular sensors: gyroscope and accelerometer. Gyroscope is comparatively stable but unreliable while accelerometer is reliable but noisy. To compensate each other, complementary filter is applied. Complementary filter is based on numerical integration since gyroscope reports time rate of angular position, while accelerometer reports angular position,. The major task is to experimentally find proper constants for numerical integration through noise due to motor vibration.

Phase 4) Building PID Loop

Basic PID loop equation is. term is responsible for time response, term is responsible for accuracy, and term is responsible for regulating overshooting. Since the constants are susceptible by physical shape of the system, the constants also can be found experimentally by applying Ziegler-Nichols Method.

Phase 5) Kinect Application

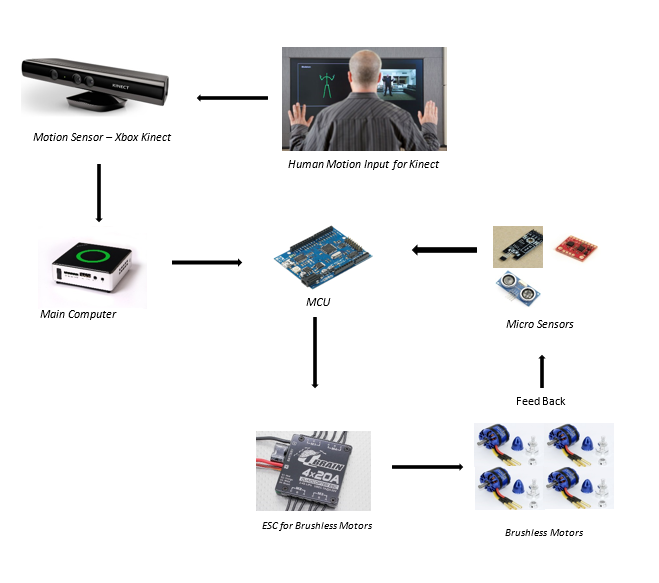
Kinect is a programmable sensor. To exploit Kinect, C# application is developed. Since Microsoft has already published and opened Kinect library, the application does not need low-level programing. However, the UAS is vibrating, the Kinect sensor values need to be damped and the corresponding constants can be sought by experiments.

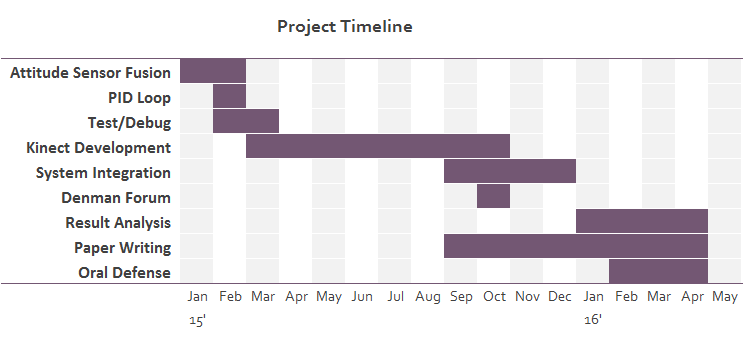
**Expected Result**

Since commercial electric speed controller converts PWM to motor output, autopilot can simply outputs PWM and feedback sensor data. Based on this feedback control loop, the drone will be able to perform linear motions – advance, retreat, left, right, descend, and ascend on a plane. Also, because Kinect has speech recognition function, a few simple command such as take-off by human voice will be possible.

**Personal Statement (Capability)**

In this undergraduate project, a simple embedded system is built for a multi-copter, which enables human motion to interact with control loop. For a dual major student, aerospace and computer engineering, this project will foster the integration of the two fields so I can pursue robotics field for the future graduate program.





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