**Navigation of a 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 during mid-20th century and has been applied for complicated and tedious attitude the control of commercial Unmanned Aerial Systems (UAS) and multi-copters due to its accuracy and simplicity of implementation. Recently, with the advances of commercial visual motion sensor, such as Microsoft Kinect, PID controller can expand its application to utilize visual motion sensors; the PID controller can directly interacts with human motions without radio-control signal by targeting a desired value set by a pilot’s visual signal. It is possible that Kinect replaces the radio-controlled signal and lead the desired value for the controller as it senses the visual motion.

This study is to perform basic rectilinear navigation of the multi-copter based on visual Kinect sensor inputs. The drone performs linear movements as the object’s relative spatial coordinate changes to execute the visual command received through the Kinect. For the integrity of the system, a micro controller unit and the Kinect application cooperate with each other. The Kinect application interprets visual data to local coordinate data, and transmits the data to the micro controller, which in turn updates the target value of the PID to modify the multi-copter’s attitude so that it can translate to the corresponding location.

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

**Introduction**

Unmanned Aerial Systems, (UAS) are playing an important role in this century due to its versatile functions that can conduct various flight-related tasks. Remote-controlled multi-copters have become a mainstream UAS 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 UASs are flourishing; with the multi-copter, one of the most popular type of air vehicle. However, learning to fly a Remote-Controlled (RC) multi-copter or a RC drone is not intuitive process, even though the needs of drone keep increasing from various industries. For instance, the high acceleration rates of UASs can be extremely challenging for untrained pilots to expect the vehicle’s movement. Pilots need a great amount of time to train to deal with these highly maneuverable aircraft. In addition, the professional missions of rescue or military task, RC pilots are often expected to be mission analysis and oversight expert as well as piloting. However, because piloting a UAS is requiring the pilot’s uninterrupted attention, a certain level of vehicle autonomy is imperative for UAS operations.

For better autonomy, remote-controller is cumbersome device for professional purposes such as rescue mission. Since such missions require fast reaction and clear communication, autopilot’s performance can increase 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 on-board 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 in-the-field workers.

- Logistics: Delivering or carrying packages.

- Rescue: On-sight surveillance and cooperation with rescuers.

- Hobby: Advancing the sport-pilot enthusiasts recreation.

Such autonomous systems are primarily composed of three sub-systems: sensing, actuating, and reasoning. Specifically, this research focuses on mostly about sensor fusion and simple reasoning control methodologies. The operational facility of the UAS and its automatic control system will be in a controlled indoor laboratory space, to provide a safe, secure and controlled testing environment.

**Objective**

This study seeks to develop the basis of such visual-based command UAS autonomy to. The developed control methodology for linear UAS motions can be a foundation of visual-based commanded autonomy, providing a proof-of-concept that UASs can recognize, with the use of Kinect system for example, an object and understand human motion and convey such commands into actual navigation. The primary objects have 3 aspects: sensor fusion, Kinect software, and the PID control loop development.

In order to feedback reliable attitude data to the PID control loop, stable values of current attitude will need to be obtained. This will be accomplished with the use of on-board accelerometers and a gyroscope. The accelerometers will provide angular position and gyroscope will provide time-rate of change of the angular position. The data outputted will be numerically integrated to generate accurate and stable angular position. 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, the research will consist of five phases:

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.

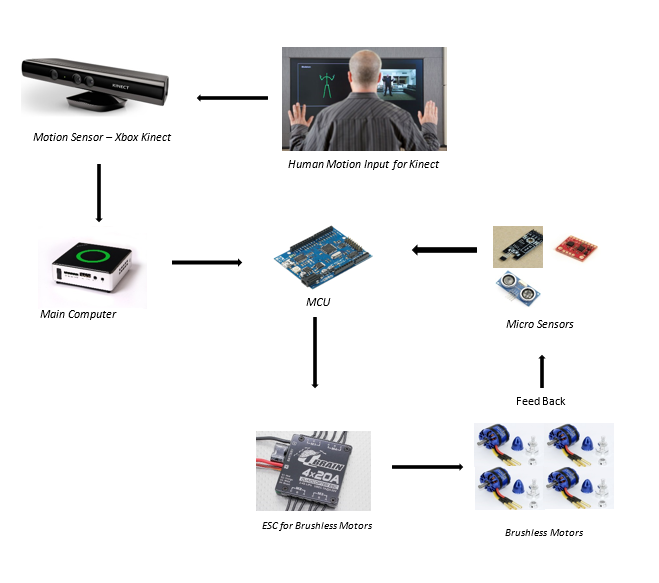
**Expected Result**

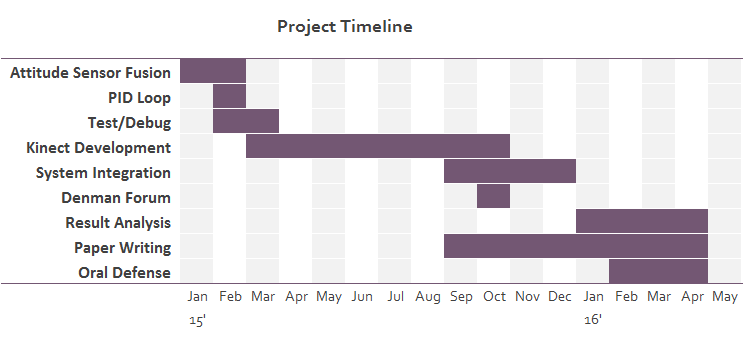
Since commercial electric speed controller converts PWM to motor output, autopilot can simply outputs PWM and feedback sensor data. Based on this feedback control loop, the drone will be able to perform linear motions – advance, retreat, left, right, descend, and ascend on a plane. Also, because Kinect 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.

The research involves





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