Control of an Quadrotor

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A quadrotor is an aircraft that has been rediscovered as a platform for many different uses, e.g. a camera platform to film from the air. Most quadrotors require a radio controller which might be hard to use for an unexperienced user and it was therefore to be replaced by a device that is accessible and easy to aquire. The choice fell upon an Android smartphone and a Sony Playstation 3®gamepad (PS3 gamepad) as replacements, since the smartphone is a common device and the gamepad is ergonomic and cheap.

The quadrotor LinkQuad, which was used in the thesis, was also to be modified into a mobile crane. It could then be used to transport loads hanging from a wire attached to the bottom of the quadrotor. However, when a load hangs from a wire and is allowed to swing freely, it might affect the flight of the quadrotor so some sort of control of the load was needed. Then heavier loads can be transported without crashing and delicate load without the risk of destruction.

Both the mobile crane problem and the replacement of the radio control could be simplified with the introduction of altitude control, since the dynamics become simpler if the quadrotor can maintain its altitude by itself.

This article will provide an introduction to how quadrotors work, the user control with a smartphone, the altitude control and the investigation around the slung load control.

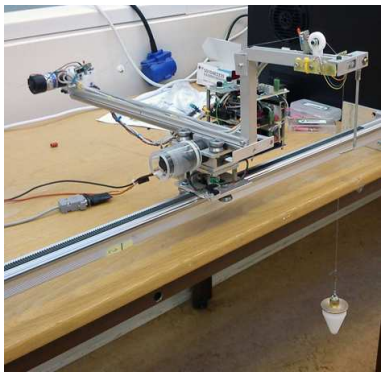
Quadrotors

A quadrotor is a vertical take-off and landing aircraft which is similar to a helicopter but is propelled by four rotors. The advantages of a quadrotor in comparison to a helicopter is that quadrotors do not require to alter the rotors during flight to adjust the thrust, e.g. to tilt the aircraft. It just increases the rotation rate of the rotors to gain more thrust and to tilt, it increases the thrust on one rotor and decreases the thrust on the opposite rotor. This removes the need for mechanical linkages to the rotors and the design is therefore simpler than a helicopter, which reduces maintenance time and cost.

A second benefit of four rotors is it allows each rotor to have a smaller diameter than what an equivalent helicopter's rotor would have to produce the same thrust. This reduces the damage the rotors would do if they would hit an object and it is therefore safer to use close to humans or to delicate equipment.

These advantages make the quadrotor an excellent air vehicle to use both indoors and outdoors and as an unmanned aerial vehicle.

(a) *The LinkQuad quadrotor and a Sony Playstation 3® gamepad.*



(b) *The miniature gantry crane.*

Figure 1: *Two of the rigs that were used in the thesis.*

User Control with Commerical Devices

A new radio link needs to be found if the radio controller is to be replaced by another device, since the frequency range of the radio controller is not supported by e.g. smartphones. However, the LinkQuad supports wireless local area networks (WLAN) just like most computers and smartphones and this became the new communication channel for the system.

Two applications, one for an Android smartphone and one for a computer, was created which allowed the user to steer the quadrotor. The Android application supplied the user with a virtual joystick and a button, where the joystick controls the motors and the horizontal rotation. When the button is pressed, the orientation of the smartphone is sent to the quadrotor and it tries to tilt in the same way.

The computer application uses the joysticks on a PS3 gamepad, where the left joystick works in the same way as the joystick on the smartphone and the right allows the user to tilt the quadrotor.

The applications support the altitude control as well by switching steering of the motor control to setting the desired altitude of the quadrotor instead.

The gamepad is ergonomic and still accurate so it is a good substitute to the bulky radio controller. The smartphone is not as accurate as the radio controller but its intuitive way of steering the quadrotor by tilting the phone itself makes it an attractive replacement too. Both applications have been designed to be easily modified so that more functionality can be added in the future.

Altitude Control

The original control of the quadrotor stabilizes its tilt angles but leaves the altitude control to the pilot. Both the future solution of slung load control and the user control could be simplified by an automatic altitude control. This would enable the pilot to focus on other tasks than to continously adjust the motors' rotation speed and it would remove most of the vertical movement of the load.

To do this, a pressure sensor is used to get a measurement of the altitude, as the pressure at a given height is proportional to the altitude. This altitude measurement is then compared to a desired altitude from the pilot and if there was an offset between the measurement and the setpoint, it compensates by increasing or decreasing the thrust of the rotors.

The altitude control is able to both maintain the altitude and to follow the user's changes of the desired altitude both indoors and outdoors.

Model of a Slung Load

The first step of the slung load control was to create a model of the load itself so that it could be simulated and control to be tested upon it.

The load was simplified as two simple pendulums, that is a pendulum that can only move in a plane, which were traversed in a cross. The movement along an axis could then be described as one of the pendulums and the movement in between axes could be described as a combination of the two pendulums.

Slung Load Control on a Crane

A miniature gantry crane was used to test the model of a slung load and to design an initial slung load control, see Figure 1b. The quadrotor with an altitude control moves only in the horizontal plane and the crane could do the same. The slung load control of the crane was therefore to be exported but the final step of exporting the software was not done in the time scope of the thesis but it is believed to be possible.

Conclusions

The user control with both a smartphone and a PS3 gamepad can be used to replace a RC controller and it allows the user control to be customized and integrated into other systems.

The altitude control was successfully implemented and the use of pressure sensor gives an altitude measurement both indoors and outdoors. It does not rely on any other systems as compared to a GPS receiver which loses its connection indoors. It is also accurate over larger intervals than a ultrasonic distance sensor, which has a range of less than 4 m and is subject to bad measurements when tilting.

The slung load control on a traversal crane could be modified and introduced to a quadrotor with altitude control in the future with some modifications for the tilting aspects of the quadrotor.

It is therefore believed that the thesis was a success.