How to stabilize a camera mounted on a moving object

A popular science summary of the master's thesis "Gyro Stabilization of a Positioning Unit"

Imagine that you want to film something out at sea, but the waves constantly make the picture swaying. Or imagine a scenario when you sit in a boat and see a person who has fallen overboard, but it is too dark outside so you lose the sight of the person, who slowly disappears among the waves... Not a fun situation to be in. But we can solve that situation! With the help of an algorithm that stabilizes a camera or a set of headlights, you never lose track of something again. This algorithm is called "gyro stabilization" and has been the goal of this master thesis.

First of all, the stabilization is performed by locking the camera in a specified direction, or towards a specific object, and saving this position configuration as the "goal" direction of the stabilization algorithm. The stabilization algorithm developed in this thesis was successfully implemented, which was proven by mounting the camera unit onto a boat, Fig 2. and driving around in the Swedish archipelago, where it could be clearly seen that the camera was stabilized during on the boat. This was further proven by mounting the camera unit on a robotic arm and jogging it around while recording video from the camera unit, see Fig 3. The videos show that the camera is pointing towards the same object during the entire experiment, while video recordings from when the stabilization algorithm wasn't activated show that the camera rotates with the robot, not able to maintain a stable frame. The idea behind gyro stabilization is to counteract for external disturbances, e.g. waves, causing the camera unit to dislocate from its desired direction. In the boat experiment mentioned above, the objective is to move the camera unit in the opposite direction of the wave with the same magnitude, so that the wave movement is counteracted, and if this succeeds, the camera unit is stabilized. This is realized by using a set of sensors, more specifically a gyroscope and an accelerometer, whose measurements tell us the position of the camera unit. This information can then be used to correct for the unwanted movements. In this thesis, the camera unit is in fact a positioning unit (PU) provided by Axis Communications AB, seen in Fig. 1.[1] The PU could be rotated about two axes using two motors (one per axis) perpendicular to each other, called pan and tilt, and could hold either a

Figure 2. Camera mounted on a boat.

Figure 1. Positioning Unit from Axis Communications AB.

[1] https://www.axis.com/products/axis-t99a10-positioning-unit-24-v-ac-dc

network video camera, or a set of illuminators (headlights). The stabilization algorithm is implemented by providing these motors with two PID controllers. Since the PU has not got a motor rotating about the roll axis, it will not be able to counteract for all introduced disturbances. The control algorithm is derived by utilizing the position data from the IMU, whose measurements are fused in a Kalman filter. This position data is compared with another position data, telling us which direction the camera unit should ultimately point at, and the error between these two positions is calculated and sent to the PID controllers in the motors. The latter position data is derived mathematically, by relating the coordinate system of the PU to an earth-fixed, global coordinate system following the cardinal directions North and East, as well as the direction of gravity. Most of the calculations and simulations regarding the stabilization algorithm were carried out in MATLAB Simulink, and later implemented in the PU's software, written in C code.

Figure 3. Camera mounted on a robotic arm.

Authors Wilhelm Andrén, Ella Hjertberg
Supervisors Anders Robertsson (Department of Automatic Control, LTH, Lund University), Torkel Niklasson (Axis Communications AB)
Examiner Karl-Erik Årzén (Department of Automatic Control, LTH, Lund University)
TFRT 6082