Implementation of control algorithm for mechanical image stabilization

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Image stabilization is a family of techniques used to reduce blurring associated with the vibration on a camera or other image devices. These techniques will not prevent motion blur caused by movement of the target subject but only rotational movement of the image device itself. However, there also exist solutions where also linear movement can be compensated for, but this is not considered here.

Background

When using cameras mounted onboard boats disturbances in the recorded image are often a problem, since waves and wind affect the position of the camera in a more dramatic way compared to land-based mountings. At Axis Communications electronic image stabilization has been used for solving the problem. However, it can only compensate for disturbances with low amplitude as the electronic stabilization reduces the size of the image shown. Due to this the stabilization could be improved by using mechanical image stabilization as well, namely, control of the camera motors to compensate for external disturbances. In this way it would be possible to suppress larger disturbances.

In Figure 1 an Axis PTZ-camera (pan-tilt-zoom) that can be used for the stabilization is shown. It is equipped with two motors that can rotate the camera dome around two axes, one horizontal (tilt) and one vertical (pan), in the plane of the page. Thus it can be used for holding the camera dome steady in some cases, but in order to suppress all types of disturbances a rotation around an axis vertical to the lens is also needed, i.e. pointing out of the page.

Figure 1: *Axis PTZ-camera model Q6155-E. Figure taken from Axis Communications*

This is easily realized by imagining a clockwise rotation of Figure 1. To suppress that kind of disturbance the camera dome needs to be rotated in the same manner in the counter-clockwise direction. A camera model that can do this is, however, not available at Axis. Thereby, the PTZ-camera is the best choice for testing the idea.

Finding camera orientation

In order to compensate for disturbances it is necessary to clearly specify how the camera dome is supposed to be oriented relative to something fixed. In this way the camera motors can be controlled so that the orientation is kept, provided that information about current orientation is available continuously. The camera is equipped with an inertial measurement unit (IMU) that can be used for measuring orientation, i.e. angle, relative to the direction of gravity and the cardinal directions. Both of these are always fixed in space. The sensor is located on the opposite side of the lens and thereby the orientation of the IMU is the same as the orientation of the camera dome. Thus it can be used for measuring how the camera dome deviates from desired orientation when it is exposed to disturbances.

Generating compensation commands

In order to keep the desired orientation, control of the motors is needed. This leads to the following question: How are the motors supposed to move in order to compensate for disturbances and thereby keeping the desired orientation? This is not trivial because the pan and tilt motors do not always suppress the same type of disturbance in orientation. For example, a disturbance in the angle relative to gravity is not necessarily suppressed by rotating the tilt motor. It depends on how the camera body is oriented relative to gravity. To clarify this, imagine a 90 degrees rotation of Figure 1 and that gravity points downwards in the plane of the page. Then it is the pan motor that must be used for keeping the desired angle relative to gravity when disturbances appear.

This problem can be solved by using information regarding orientation, motor position and desired orientation. The motor position, i.e. motor angle relative to an origin position, can be measured by encoders that are attached to the motor axes. The information gives an opportunity for finding the angles for pan and tilt that results in a desired orientation. Since this information is available continuously it is possible to find the angles at all time. If a disturbance appears, then the angles will change values, and moreover, they are commanded to the pan and tilt motors continuously. Figure 2 shows a simulated command signal generation for the tilt motor when the camera body is oriented like in Figure 1 and gravity points downwards in the plane of the page. A sinusoidal pitch disturbance affects the camera body, meaning that the disturbance affects the angle relative to gravity. In this case the desired angle is zero and it is obvious that only a tilt command should be generated in order to suppress the disturbance. Moreover, for a successful disturbance suppression in this case, the tilt angle should be the negative value of the disturbance at all time, because then the sum of the two will be zero, meaning that the disturbance is canceled out. This is also what Figure 2 shows.

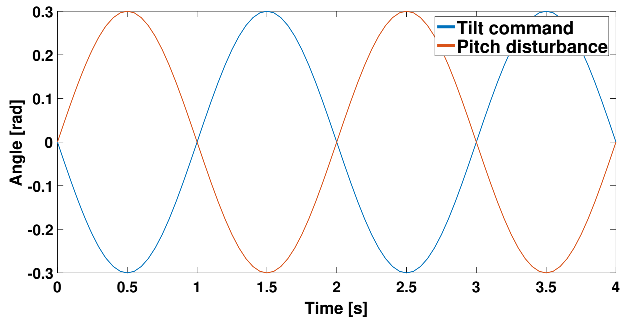

Figure 2: *Sinusoidal pitch disturbance and tilt command signal*

Control

In order to track the compensation commands generated for the pan and tilt motors some kind of controller is needed. A very common controller that can be used for this purpose is the PID-controller (Proportional-Integral-Derivative). Based on a control error, i.e., in this case the difference between measured encoder value and encoder value given by the compensation commands, and some other configuration parameters, it generates a control signal. In this case the control signal decides how fast the motors are supposed to move in order to make the error equal to zero. A large control error will produce a high motor speed since the error must then decrease quickly and in the opposite case a smaller speed is produced.

If the PID-controller can be used for perfectly tracking the command signals, a perfect disturbance suppression is obtained.

Result

In Figure 3 the pan tracking result can be seen for a command signal of 1Hz. It is clear that the tracking is good but it is not perfect, since there is a time delay present. However, the result shows that the concept described can be used for obtaining a significant suppression of external disturbances.

To read a more detailed description of the stabilization technique presented in this article, a Master's thesis with the same name and authors is available.

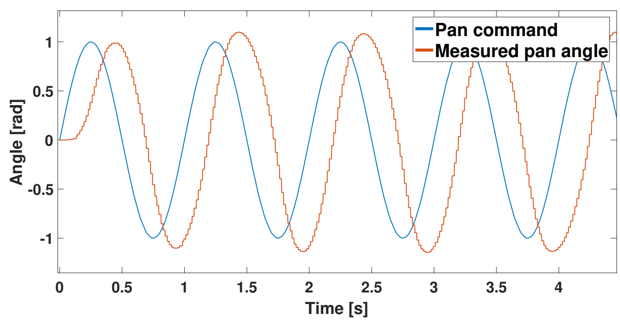

Figure 3: *Tracking of a pan command signal with the frequency 1Hz*