A Low-cost and Low-weight attitide Estimation System for an Autonomous Helicopter

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1) In the paper the signal of the gyro-sensor is integrated. In this way the speed of rotation is turned into an estimate of the angle of rotation. Another example of integration of a sensor signal is the case were an accelerometer is used. Here a position estimate can be derived by double-integration of the acceleration signal. The paper demonstrates one major disadvantage of the integration process.

- What is this disadvantage?
- Discuss what the possibilities are to reduce this disadvantage?

2) The process of integration of a sensor signal also has another disadvantage (which is not discussed in the paper).

- What is this disadvantage (hint: what happens in case of sensor saturation).

3) The opposite of integration is derivation of a sensor signal, for example in case the position is measured by a sensor and the speed is derived by derivation of this sensor signal.
For example, in commercial robot arms there is a sensor to measure the joint rotation of a rotational joint (for example an encoder). The speed of the robot arm, which is necessary to know for the joint controller, could be derived by derivation of the encoder signal. However, often the speed is measured as well with a separate sensor, for example a tachometer. Derivation has probably a disadvantage to justify the costs of a second sensor.

- What is this disadvantage (hint: what happens with a noisy sensor signal)
- Discuss what happens at very low speeds of the robot joint in the example above if one only would use an encoder.
- What can you to reduce the effect of the disadvantage
  if you do not want to buy another sensor which measures the required signal directly.
- In sampled systems the sample time T is an important factor. Why ?

4) The paper shows that the dynamics of a sensor are important to take into account. The inclinometer acts as a low-pass filter.

- When becomes the dynamics of a sensor relevant for a certain application?
- What do you need to know about the application to be able to decide whether the dynamics of the sensor are an issue ?

5) In practice you will almost always try to find a sensor so that the dynamics are not an issue. A problem is though that not all sensor suppliers provide reliable and good information of the sensor dynamics. This information is most ideally a bode-plot of the input-output relation of the sensor. If you can find out the dynamics of a sensor, how would you find the dynamics of the sensor in case you had the sensor in-house ?

6) The inclinometer acts as a low-pass filter. What if you would have a sensor which acts as a high-pass filter? Discuss what this would mean in practice, take as example an accelerometer. What can you measure and what not ?

7) This paper deals with the combination of two sensors. One sensor which acts as a low-pass filter and therefore cannot be used alone for the helicopter application. One low-cost gyro, which has a rather high drift after integration (a cost issue !) and therefore cannot be used alone for the helicopter application. By

combining the sensors and appropriate signal processing based on models of the sensors, a nice sensor system is achieved.

- What would happen if you would use a very expensive gyro with very low drift (instead of around 200 dollars, 10.000 dollars or more ?