Myths surrounding gyroscope sensors and balancing robots:

1. a Kalman filter is necessary
2. a “complementary filter” is necessary
3. PID control is sufficient to balance
4. an accelerometer is necessary
5. wheel encoders are necessary
6. the gyro needs constant calibration
7. need to convert gyro reading from angular frequency to angle

Kalman filter - I build balancing robots without Kalman filters or any noise filtering. It is just not necessary. If you look at an example gyro output the signal looks clean. Why would you want to mess with a filter when none is necessary.

Complementary filter - The theory is that the gyro gives insufficient information so additional information must be added from an independent source. I'll just say that I get really good results with only a gyro.

PID control - You can balance with just PID control but if you give the robot a push or have an offset in the gyro output you will cause the robot to fall. Refer to... http://ctms.engin.umich.edu/CTMS/index.php?example=InvertedPendulum&section=ControlRootLocus . Jump to the bottom of the above link to see what I am talking about.

PID control looks like this (parameters a, b, and c are positive numbers)...

$$\frac{a\,s^2 + b\,s + c}{s}$$

In order to balance you need PID control plus positive feedback. Refer to... http://www.ece.utah.edu/~ece3510/lab_Inverted%20Pendulum_S05.pdf .

PID control with positive feedback looks like this...

$$\frac{a\,s^2 + b\,s + c}{s^2 - d\,s - e}$$

Note that in the above expression one pole has a positive real part making the controller unstable by itself.

This is the controller I use...

$$\frac{a\,s + b}{s^2 - c\,s - d}$$

My model works so well I can come pretty close to the optimum parameters using simulation. Fine tuning is done by trial and error. I don't have any onboard pots or adjustments.

Positive feedback seems to be necessary. If you are balancing with a "**complementary filter"** you are introducing positive feedback. If you are balancing with a gyro and an **acceleromete**r you are introducing positive feedback. If you are balancing with a gyro and **wheel encoders** you are introducing positive feedback.

The gyro may **drift** a little but this will not cause the robot to fall over. Offset translates to speed. Since offset drift happens slowly, there is plenty of time to adjust the robot speed with whatever control you have implemented to adjust speed.

People seem to be uncomfortable thinking in terms of **rate of angle change**, θdot, vs **angle**, θ. If your tilt sensor gave you units of θ and your controller has gain F(s), then a sensor giving you units of θdot would require a controller with gain $\frac{F(s)}{s}$. In other words, you design the controller to accept whatever input you have available from the sensor. This is possible because θdot and θ contain the **same information** but in a different form.

Information on my model at... http://nxtotherway.webs.com