Gyrobot
a Two Wheel Balancing Robot

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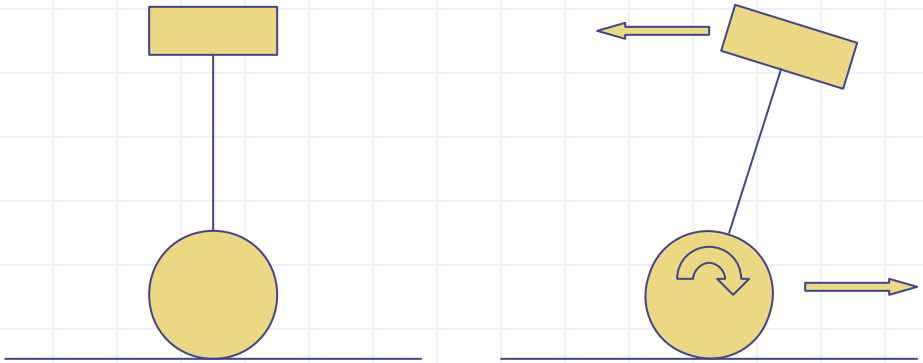
http://www.barello.net/Robots/Gyrobot

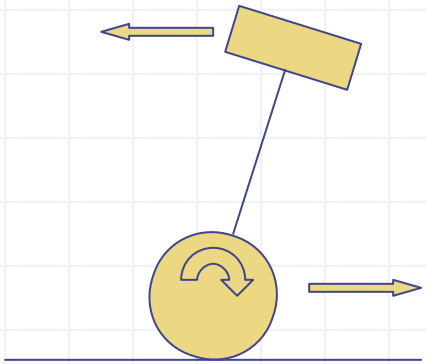
How Balancing Works

- Sense tilt and drive wheels to make robot erect.



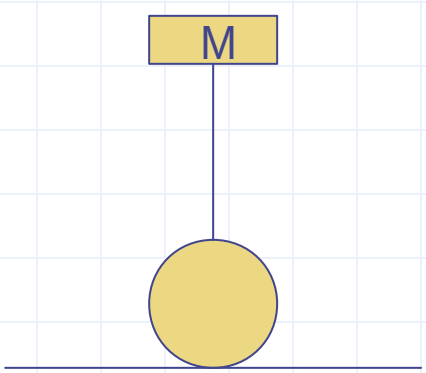
- Easier to balance high GC object.
- The Devil is in the details.

How Balancing Works

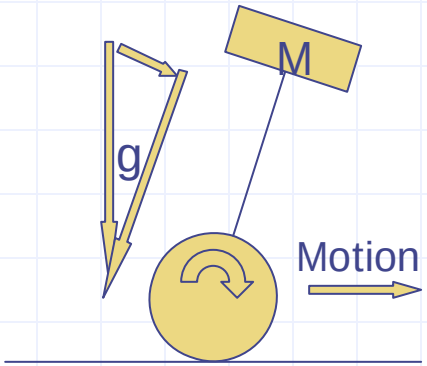


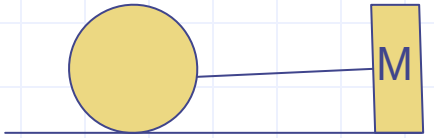
- Restoring Torque = ω * Kω
- ω = Angular rate (deg/sec)
- Kω = some factor based upon robot mass & moment arm.

How Balancing Works



T = M * g * sin(0)





T = M * g * sin(90)

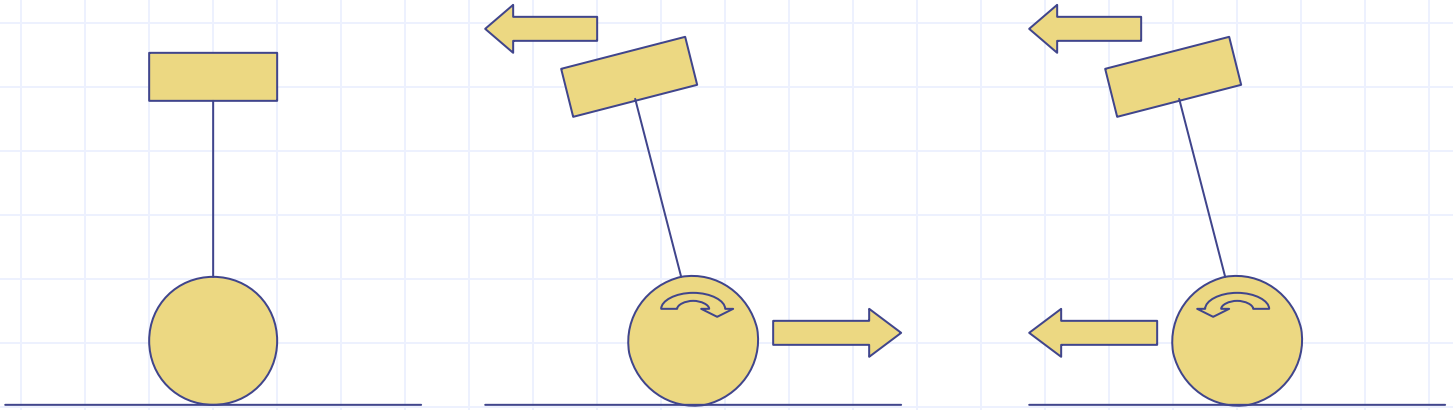
- Balance torque = M * g * sin(angle)
- M is moment arm (center of mass & distance from pivot).
- g = acceleration of gravity
- Angle is deviation from balance point

Controlling Drive Torque

- As velocity increases, DC motors have less torque (back-EMF)
- Need to correct this so balance equation can work.
- Positive velocity feedback
- Drive = drive + Kv * velocity
- Kv = factor based upon motor specification.

How to move

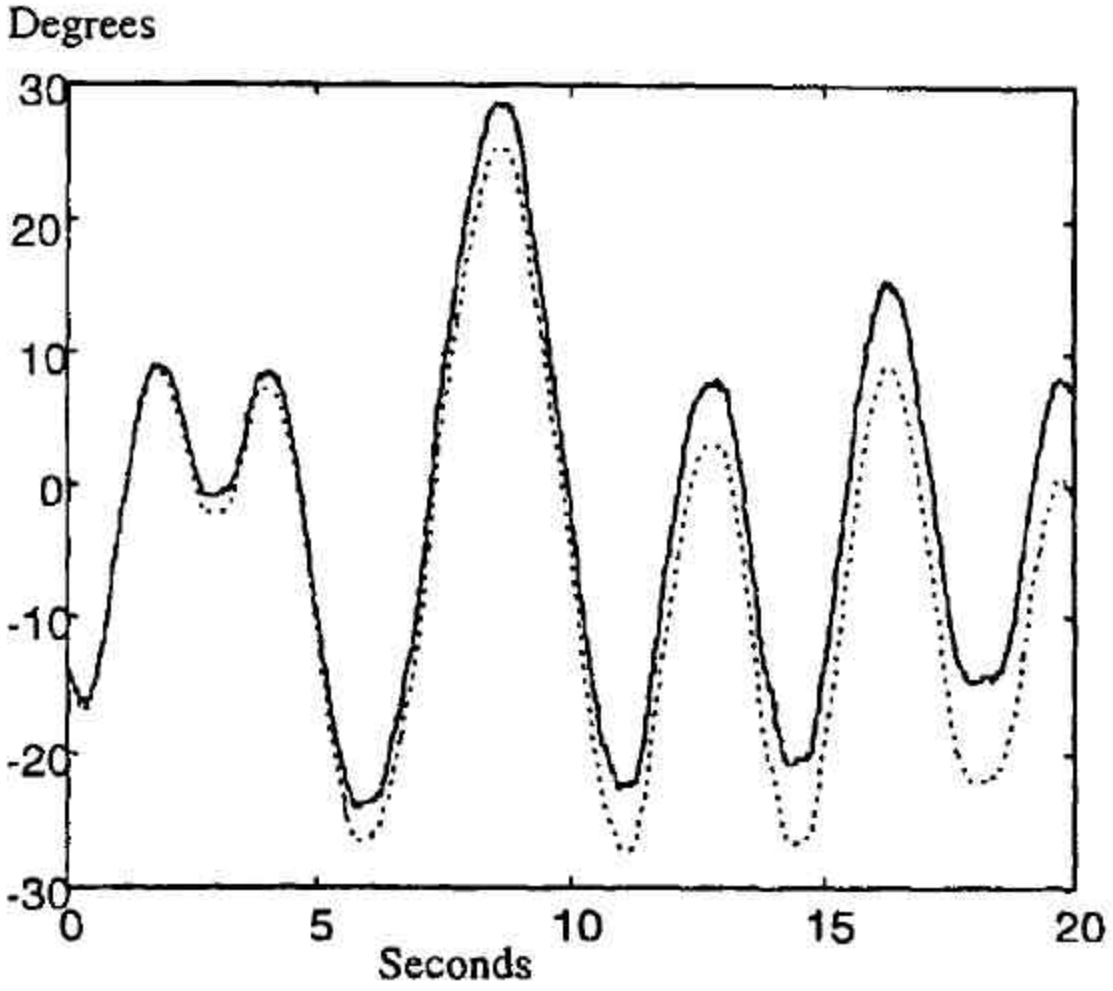
- The robot tilts in the direction of movement.



- To move robot, need to adjust “balance angle”
- By adding an error to the angle, the robot will drive a little backwards, then forwards trying to maintain the “balance angle”
- Error can be simply a negative drive value.

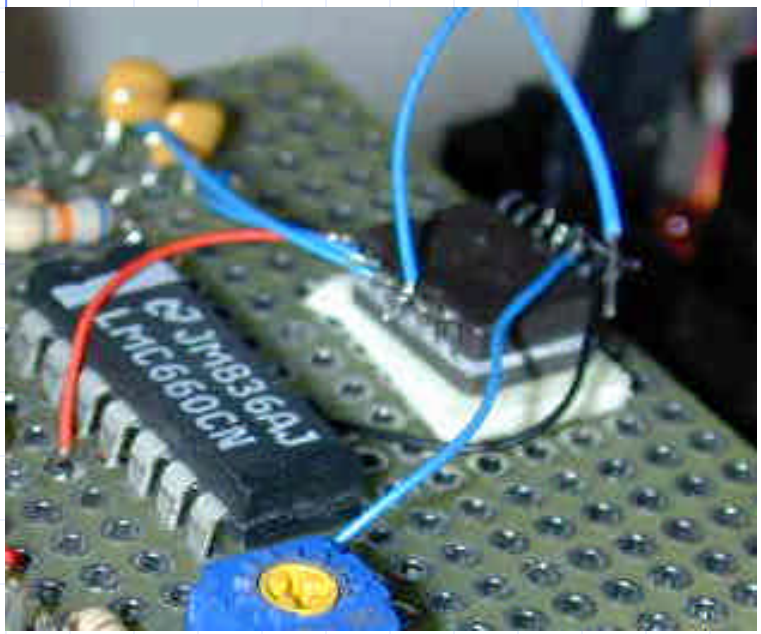
Tilt Sensor

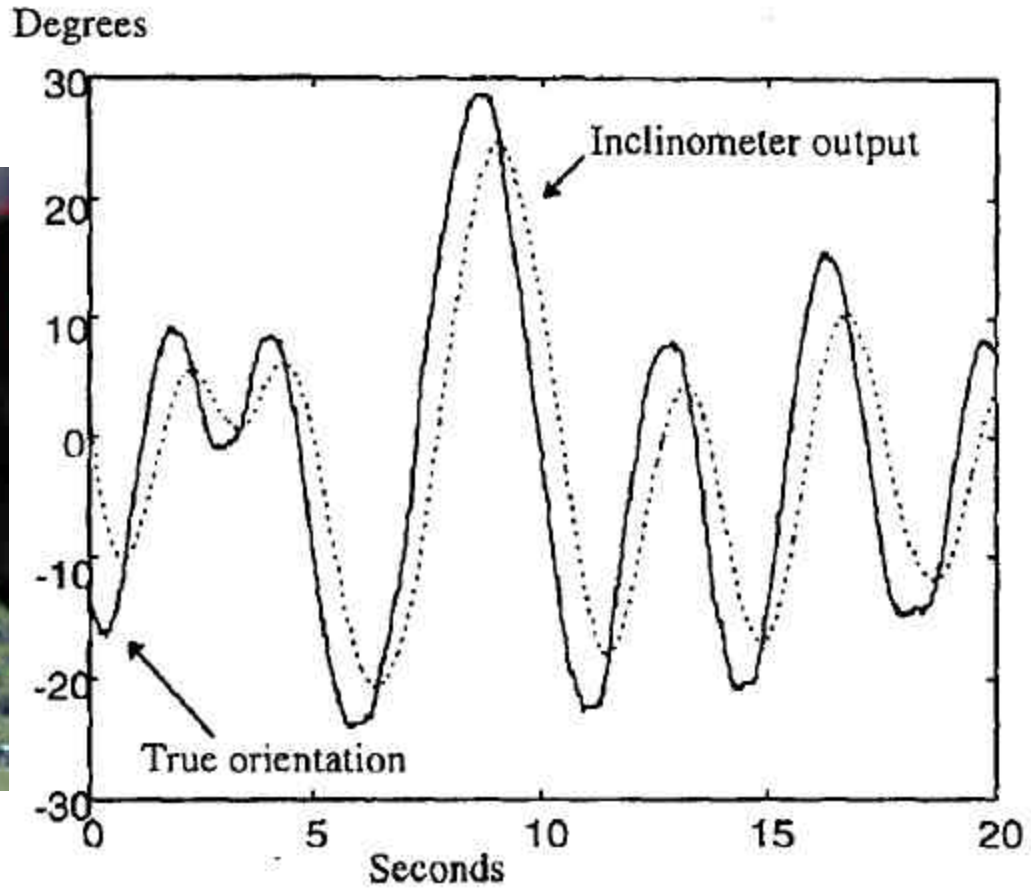
- Gyroscope measures Rate Of Turn.
- Integrate for angle
- Gyroscopes drift
- Drift changes with temperature



Tilt Sensor

- Accelerometers measure gravity.
- Affected by movement.
- Very accurate.



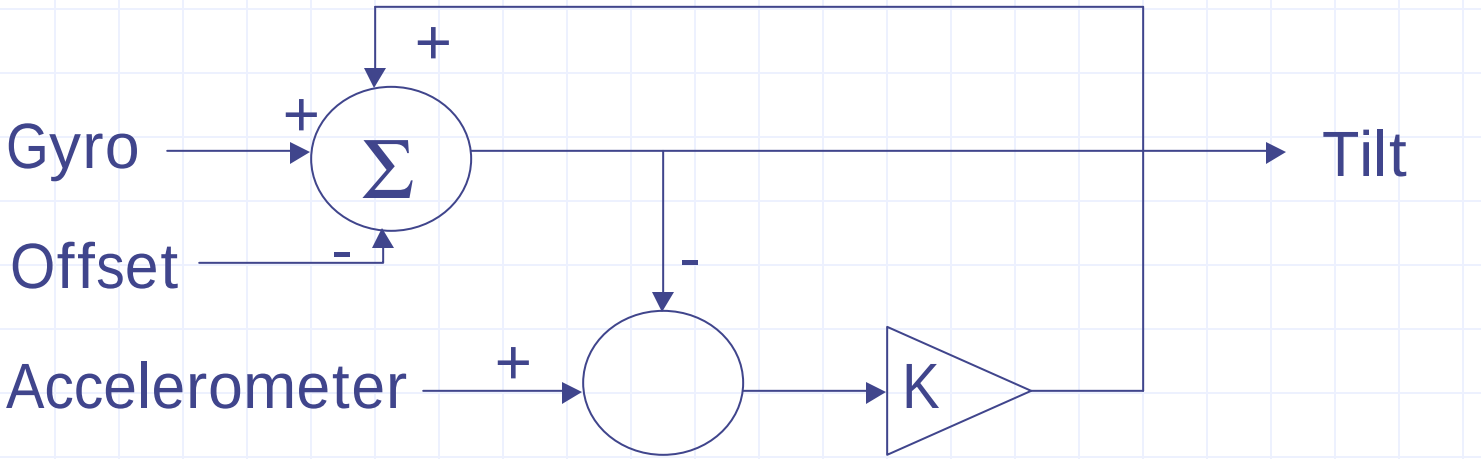


Fusing Gyro and Tilt sensors

- Weighted Average Filter.
  - Use fraction of error between tilt and gyro
  - Add to integrated Gyro output.
  - Results are fast & drift free
- The weighted average IIR filter technique can be used to smooth out any noisy signal.

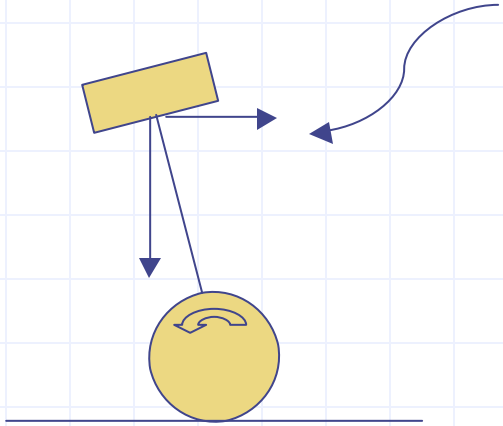
Fusing Gyro and Tilt sensors

- Weighted Average Filter.
  - $Tilt_{gyro} = Sum(Gyro - Offset)$
  - $Tilt_{accel} = \sin^{-1}(x/g)$
  - $Tilt_{gyro} = Tilt_{gyro} + (Tilt_{accel} - Tilt_{gyro}) * K$



K = weighting factor (1%)

Alternate to Tilt Sensor



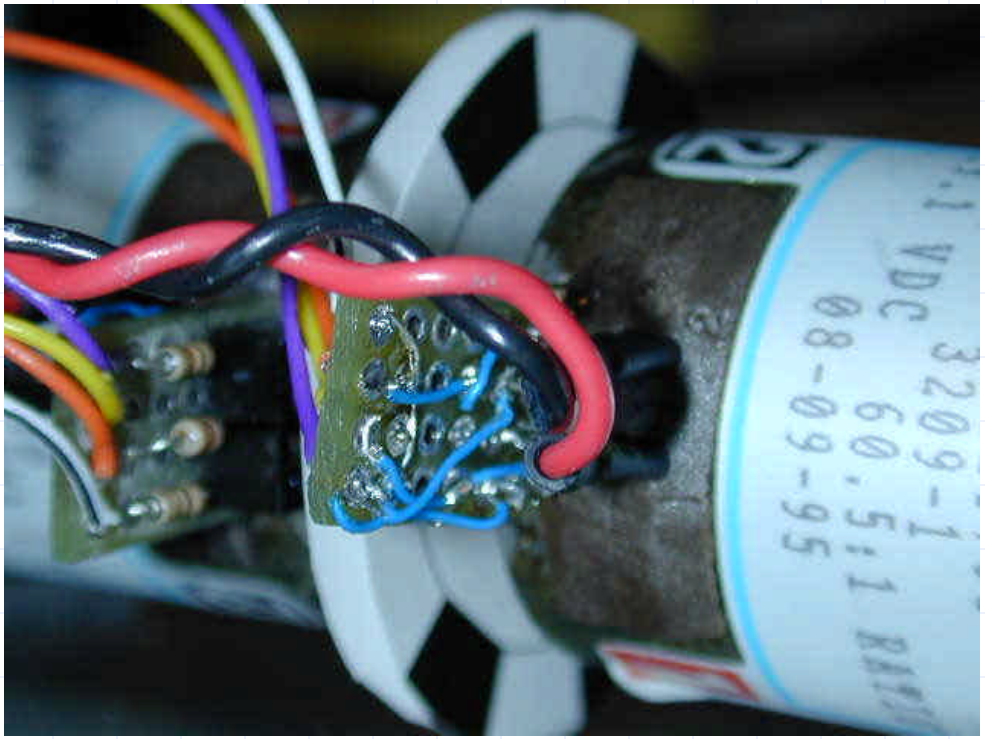
- $F = g * \sin(\text{theta})$
- $F = A * m$
- $A * M = g * \sin(\text{theta})$
- $\text{Theta} = \sin^{-1}(A * m/g)$

- m = mass
- A = Acceleration M/S^2
- g = Gravity
- F = force

Presumably we can use the acceleration of the robot to infer the angle of tilt and correct for gyro drift. (Note: Moment arm not included, formulas must be wrong)

Motion Sensor

- Encoders measure position and velocity of wheels.
- Dead reckoning can be derived from encoders and the robots position determined in X, Y and Theta.



Current Status

- Motion control not implemented.
- Navigation disabled.
- Remote control (Radio link) not implemented.
- Using acceleration to correct tilt not tried.

In short, it doesn’t do anything interesting yet.

Additional reading

- Robots & controls
  - www.barello.net/Papers/Motion_Control
  - Pendulum Joe http://leiwww.epfl.ch
- Data sheets
  - http://www.systron.com/prodinfo/AQRS.html
  - http://products.analog.com/products/info.asp?product=ADXL202