# Self-Balancing Robot

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GOOGOL TECHNOLOGY

An inverted pendulum system is a highly coupled multivariable, nonlinear and unstable system. It is the perfect experimental device to examine various control theories. Controllability, stability, robustness and some other key performance in control will be examined in the process of controlling such system.

The self-balancing robot is in fact a movable 3 DOF inverted pendulum system. The system, taking the gyro as feedback, is balanced by outputting different torque in two wheels.

**System Model**

$$\begin{bmatrix} \dot{x}_r \\ \ddot{x}_r \\ \dot{\theta}_p \\ \ddot{\theta}_p \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & A_{23} & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & A_{43} & 0 \end{bmatrix} \begin{bmatrix} x_r \\ \dot{x}_r \\ \theta_p \\ \dot{\theta}_p \end{bmatrix} + \begin{bmatrix} 0 \\ B_2 \\ 0 \\ B_4 \end{bmatrix} [C_\sigma]$$

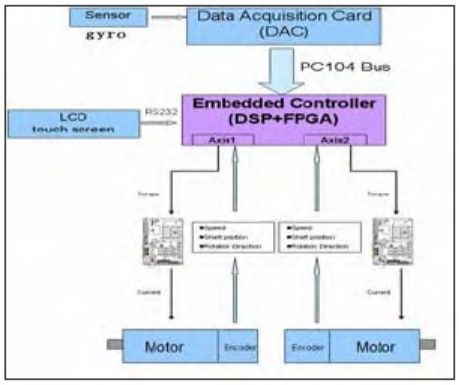
$$\begin{bmatrix} \dot{\delta} \\ \ddot{\delta} \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \delta \\ \dot{\delta} \end{bmatrix} + \begin{bmatrix} 0 \\ B_6 \end{bmatrix} [C_\delta]$$

$x_r$ Robot Position; $\theta_p$ Robot Tilting angle $\delta$ Robot Yaw angle $C_\delta$ Torque of motor

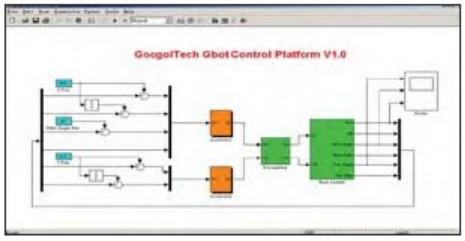
**System Characteristics:**

1. More degree of freedom compare to linear and planar inverted pendulum
2. Using real-time workspace in MATLAB
3. Embedded PC104 system with windows operating system
4. Online editing & modifying the control algorithm
5. Various extension interface for add-on sensors, e.g. vision
6. Providing MATLAB functions

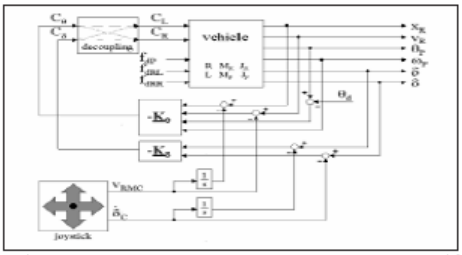
**System Diagram**




**MATLAB Interface**




**Plant Diagram**




| Specifications | |
|---|---|
| L x W x H | 260mm x 450mm x 730mm |
| DC Servo Power | 85W |
| Gear Ratio | 8:1 |
| Motion Controller | • DSP and FPGA based embedded Controller<br>• PC104 bus<br>• 3 Axes Motion Controller |
| Software Environment | WIN 98/ MATLAB 6.5 |
| Maximum Speed | 1.6m/s |
| Power | NiMH Battery 8.5Ah (24V) |
| Duration | >1.5H |
| Maximum Loading | 3 Kg |
| Maximum Ramp Angle | 20 Degree |
| Gyro | • Power 9~12V<br>• AD/DA resolution 12 bits<br>• Current 30mA<br>• Maximum angular velocity ±300 deg/sec (25°C)<br>• Range 360° (25°C)<br>• Sampling Frequency 150HZ<br>• Temperature Bias ± 0.025%/°C<br>• Operating Temperature –40~50°C<br>• Analog Output (0~4.096V)<br>• Repeatability 0.10°<br>• Weigh 20g |

**Ordering Guide**

| Model Number | Product Name | Product Configuration |
|---|---|---|
| GBOT-1001 | Self-Balancing Robot | • Self-Balancing Robot Main Body<br>• Self-Balancing Robot Software<br>• GoogolTech's Simulink Toolbox |

**Reference Experiments**

- Gyro application and experiments
- System Modeling
- Open Loop System Analysis
- PID Controller Design
- Pole Placement Controller Design
- LQR Controller Design
- User Defined Controller Design