Development of a ball-balancing robot with omni-wheels

Magnus Jonason Bjärenstam   Michael Lennartsson

March 16, 2012

Today most people are familiar with what a Segway is and how it works.[1] The rider can go forward and backward by leaning and turn by tilting a handle. The robot presented in this article reminds of a Segway without a rider, see Figure 1. The function is basically the same but with one major difference, it can move in any direction without turning, e.g. it can also go sideways. This is possible by the use of omni-wheels. An omni-wheel is a special kind of wheel with rollers along its circumference, see Figure 2. It can roll forward as an ordinary wheel but at the same time it can slide sideways due to the rollers. The robot's base consists of three omni-wheels in a special configuration, see Figure 3. Each wheel has a motor connected to it. The omni-wheels are always in contact with the ball and by turning them in a certain combination, the ball will roll in a certain direction. The relation between the omni-wheels' motions and the robot motion are described by a kinematic model, see thesis report [1].

The balancing problem can be looked upon as an inverted spherical pendulum in the xy-plane. In order to stabilize an inverted pendulum the angle and angular velocity of it must be known. They are measured by using an accelerometer and a gyroscope. It is desired to not only stabilize the robot but also keep it in a certain position. By inverting the kinematic model estimations of the speed and position of the robot can be calculated. Now all eight states, four in each direction, needed for state feedback control are known. The robot was modeled on a computer using the software Dymola and then Matlab was used for calculating the state feedback matrix [2],[3].

The heart of the robot is a micro-controller, Arduino Mega 2560. It handles all communication with the motors and sensors. The control law algorithm is also implemented on the micro-controller. The robot is designed to stand right up balancing on the ball and keep its position around the starting point. The authors are pleased with the performance of the robot, see Figure 4. A video of the robot is available at YouTube, `www.youtube.com/watch?v=eqhnZmMAU6M`

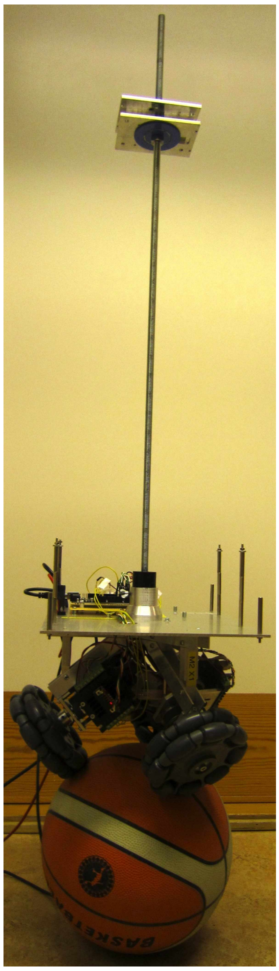


Figure 1: The Robot.

[1] A Segway is a two-wheel balancing vechile, see `http://www.segway.com`.

Figure 2: Picture of an omni-wheel which can roll both in "normal wheel direction" and perpendicular to it due to the extra rollers along the wheel.

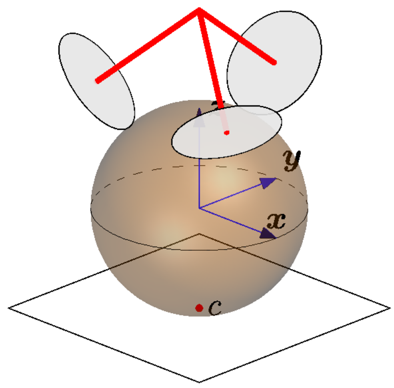
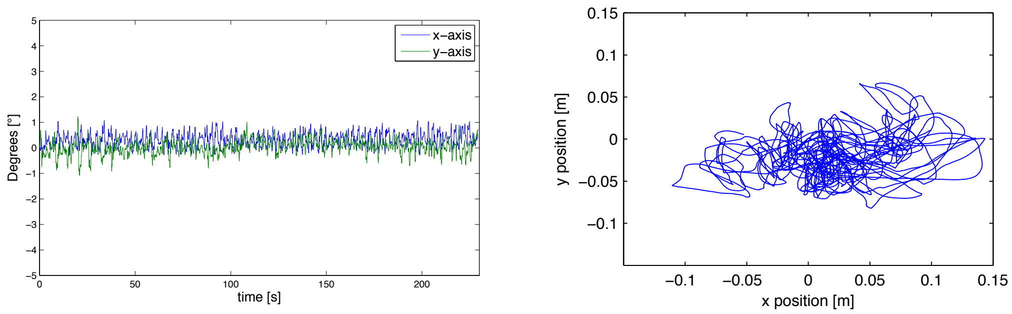


Figure 3: The omni-wheels are placed symmetrically around the Z-axis and perpendicular to the surface of the ball.



(a) Balancing (angle with respect to ground normal).

(b) Positioning in XY-plane (should ideally be standing still)

Figure 4: Performance of the robot during 230 seconds.

References

[1] M. Jonason Bjärenstam and M. Lennartsson. *Development of a ball balancing robot with omni wheels*. Master's Thesis. Department of Automatic Control, Lund University, Sweden, 2012. ISRN: LUTFD2/TFRT–5897–SE. URL: `www.control.lth.se/Publication/5897.html`.

[2] *Dymola*. URL: `www.3ds.com/products/catia/portfolio/dymola` (visited on 2012-02-21).

[3] *Matlab*. URL: `www.mathworks.se/products/matlab/` (visited on 2012-02-21).