Improved Mechanical Model of the „Ball Balancing Platform“

Degree programme: BSc in Micro- and Medical Technology | Specialisation: Robotics
Thesis advisors: Dominik Hofer, Fabio Modica, Prof. Dr. Thomas Niederhauser
Expert: Juan Fang

The „Ball Balancing Platform“ (BBP) is currently used in practical training for learning and understanding feedback control systems. Its applications are limited by the mathematical model constraining the kinematics to two degrees of freedom (DOF). This thesis aims to expand the mathematical model of the inverse kinematics to three DOF and to develop a simulation of the mechanical model and to accurately animate the BBP in Matlab/Simscape.

Introduction

The BBP is used to balance a ball on a touch panel, which is driven by three DC motors (see Fig. 1). Each motor is connected to the plane by an arm, consisting of a rotary joint (1 DOF) and a spherical joint (3 DOF). To adjust the position of the ball on the touch panel, it is necessary to tilt the table around the roll and pitch angle (see Fig. 2), so only two DOFs are needed for this application. The kinematic model is now extended for this thesis by considering the third DOF (translation in the z-direction). By extending the inverse kinematics, which is used to calculate the angles of the motors from the platform position (pitch, roll, z-position).

Goals

- Derive and implement the inverse kinematics for three DOFs of the plane
- Mechanical simulation and animation of the BBP
- Measuring gravitational acceleration using the implemented kinematical model

Methods

The inverse kinematics has been developed using the model of a system called „the Steward / Gough platform“ . By calculating the Cartesian distances of defined points (P_W on the touch panel plane and P_B on the basis), it is possible to calculate the angle of the DC motors. To prove the accuracy of the mathematical model of the kinematics, different angles of the motors have been calculated using a Matlab algorithm. Moving the motors to the predefined angles, the coordinates of the panel are measured, using an IMU sensor and a telescopic measurement device. The measured position is compared with the values calculated with the inverse kinematics. To demonstrate the usefulness of the third DOF, the gravitational acceleration is measured using the principle of free fall, accelerating the platform downwards. As soon as the ball detaches from the touch panel, the acceleration of the platform is equal to the Earth‘s gravitation. The acceleration measurement is done using the motors encoder position data. Transforming the positions of the motors, with a simple model of the forward kinematics, the z-position of the platform is calculated. Using a double derivation of the positions in z, the acceleration in z of the platform is obtained.

Results

- Without accounting for measurement imprecision, the accuracy of the derived inverse kinematics gives an average relative error on height of about 1% (min 0.55%, max 1.47%) , for pitch and roll of about 3% (min 0.5%, max 6.6%).
- A Simscape model was created to simulate and animate the movement of the BBP.
- In a sample expermient performed in the city of Biel, gravity has been estimated as 9,816 m / s^2.

Giedi Ennio Bernasconi
077 404 77 37
giedi.ber@hotmail.com

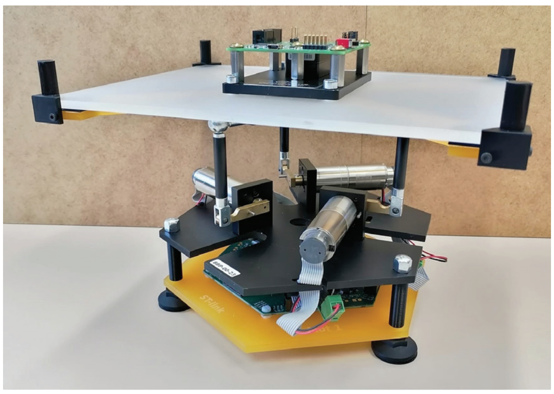

Figure 1: Ball balancing platform with IMU Sensor

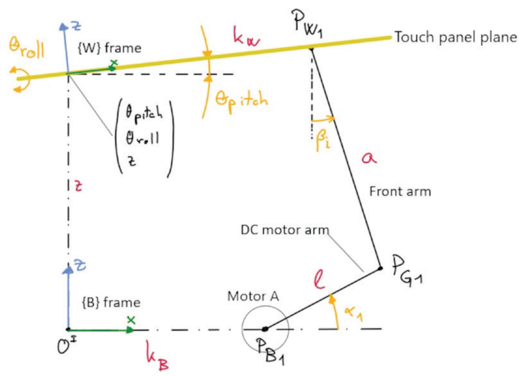

Figure 2: Section of the first arm of the BBP