Improved modeling of Mecanum wheels for mobile platforms

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EXTENDED ABSTRACT

1 Introduction

Since the invention of the Mecanum wheel in 1972 by Bengt Ilon, it is used in numerous industrial applications. By controlling each wheel individually, a vehicle with three or more Mecanum wheels can follow arbitrary trajectories. This so called omnidirectional motion is beneficial when operating in environments with narrow paths and leads to applications as in warehouses and industrial environments [1].

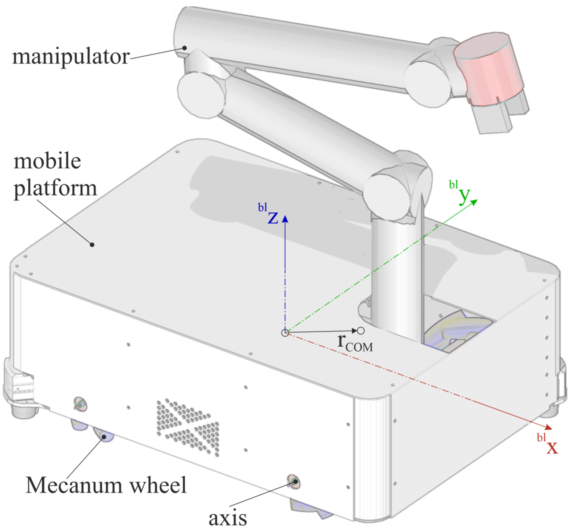
In this work, we present an improved dynamic model for Mecanum wheeled platforms and validate the presented model using measurements. The model parameters $\mathbf{p}$, containing e.g. friction and the center of mass, are calibrated using the measurement data. In most applications the twist $[v_x,\ v_y,\ v_z,\ \omega_x,\ \omega_y,\ \omega_z]^T$ of Mecanum wheeled platforms is simplified by using the kinematic equation [2]

$$\begin{bmatrix} v_x, & v_y, & v_z, & \omega_x, & \omega_y, & \omega_z \end{bmatrix}^T = \mathbf{f}_{\text{mbs}}\left(\boldsymbol{\omega}_{wheel}, \mathbf{p}\right) \quad \rightarrow \quad \mathbf{v} = \mathbf{J}^{+}\boldsymbol{\omega}_{wheel} \tag{1}$$

with the local velocity $\mathbf{v} = [v_x,\ v_y,\ \omega_z,]^T$, the pseudoinverse of the Jacobian $\mathbf{J}^{+}$ and the angular velocities of the wheels $\boldsymbol{\omega}_{wheel} = [\omega_1,\ \omega_2,\ \omega_3,\ \omega_4]^T$. As it is known from measurements that the real robot's motion deviates from this kinematic equation, Han et. al [3] introduced factors in Eq. (1) to calibrate the kinematic equations. During laboratory experiments we observed that shifting the center of mass (COM), e.g. by moving the platforms manipulator or adding payload, increases the trajectories curvature greatly, while also slippage and geometrical errors in the wheels production and friction influence the accuracy of positioning. We show that the multibody model of the robot using this Mecanum wheel model reproduces the twist including elasticity of the wheel-ground contact and tilting of the robot, which the simplified kinematic model cannot, while still using an efficient model.

2 Methods and preliminary results

In this work we show non-ideal behavior of dynamic trajectories of a real robot and the capability of our simulation model to show the same behavior. Measurement data was obtained using the mobile robot Leobot, an open hardware mobile manipulator [5] designed for operating in industrial environments. The robot's motion is tracked during the experiments using a *vicon* motion tracking system. The motion is partitioned into 4 different parts, shown in Fig. 2, left. The wheel velocities of the mobile manipulator are controlled according to the kinematics equation. The obtained data is compared with the multibody simulation



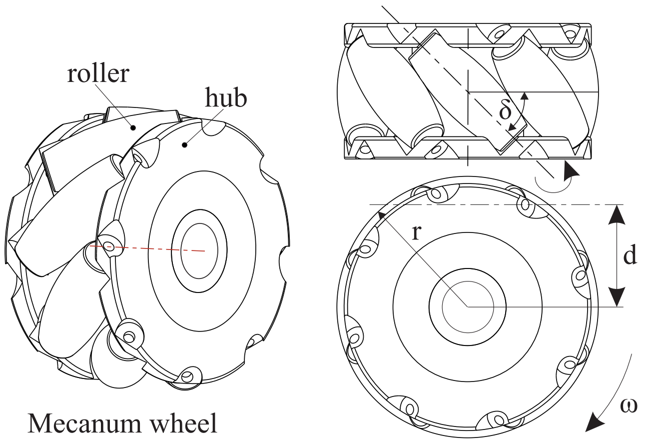


Figure 1: *Left*: Multibody dynamics model of the robot. Arm motion results in a change of the center of mass (called *configuration* 1 to 4 in Fig. 2), influencing the platforms motion. *Right*: The basic geometry of a Mecanum wheel. The rollers can rotate freely and are typically mounted on the hub with $\delta = 45°$ and a distance of d. The rollers geometry is chosen so that the contact point, while moving along the hub's rotation axis, is still located on a cylinder with radius r [4].

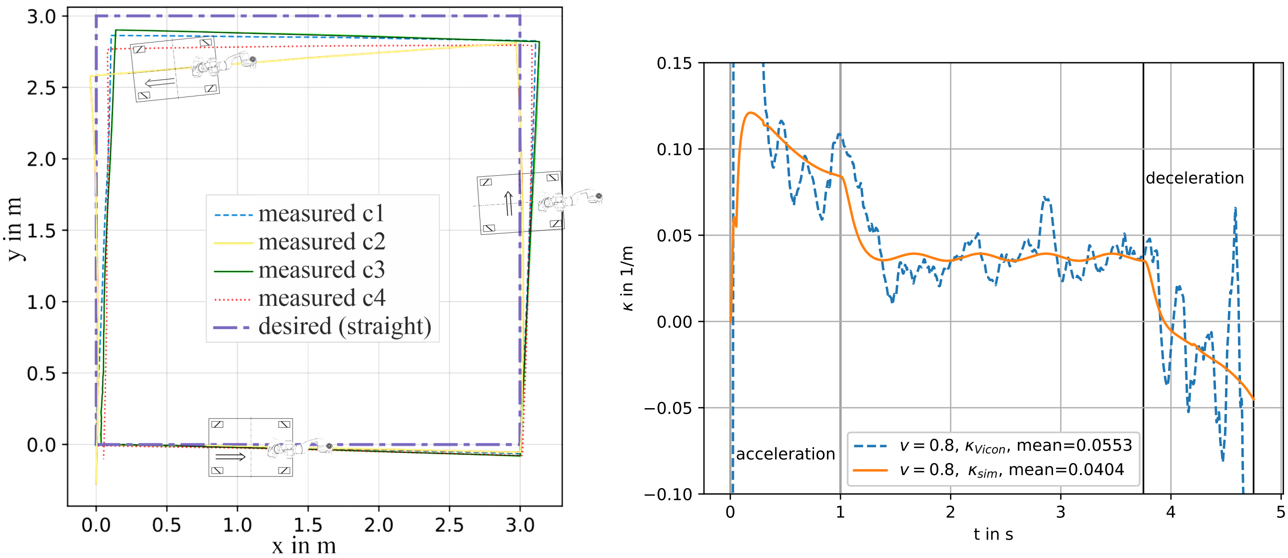


Figure 2: *Left*: Set of measured trajectories with variation of the center of mass (configuration c1 to c4) and the desired, straight trajectory is calculated from Eq. (1) and remains constant for all trajectories. *Right*: The curvature κ of the lateral right motion of configuration 2, where the COM is shifted to the front.

model whereby the measured angular wheel velocities $\boldsymbol{\omega}$ are used as input for the multibody dynamics simulation model created in the Python library Exudyn [6]. This model consists of the main body, displayed by the chassis in Fig. 1, (left), and 4 wheels which are in contact with the flat ground. The wheel-ground interaction is modeled using the orthotropic friction model from [7] with the extension of a linear regularization term and a velocity dependent term in the orthotropic friction force.

To assess the model we compare the trajectory's curvature in the ground plane of the measured and simulated trajectories, shown in Fig. 2, right. The mean curvature of the proposed model fits well with the measurement, both in the constant velocity regime and during acceleration/deceleration. The proposed model does not include the Mecanum wheels individual rollers and can therefore not represent the robot's vibrations, see Fig. 2. In the paper we show in detail the derived equations for the Mecanumwheel, the model of the mobile platform and compare it with the measurement data obatained from the real robot. In the outlook we briefly show a detailed multibody model with individual roller contact.

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