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Modeling and Kinematic Control of an Omnidrive indoor Robot Platform

Objective

- Realizing an autonomous Omnidrive platform
- Modeling the kinematic control
- Identifying the system parameters
- Data fusion for path tracking

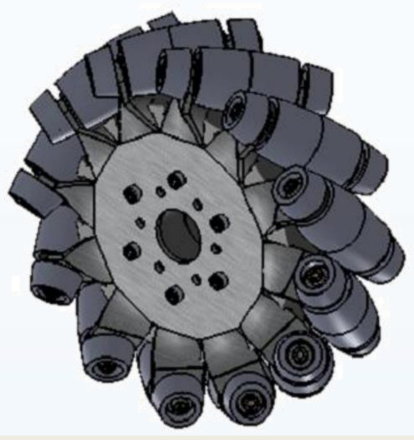
Description of the system

We choose to develop an omni-directional platform that will be added to the robot arm used for a medical application of Curietherapy.

InTraDE omnidrive robot plateform.

Mechanical Design

- Made of aluminum profile,
- A rectangle configuration with a 900 [mm] long and 700 [mm] wide,
- Two mecanum wheels on each side of the chassis, actuated by its own DC MAXON motor.



Mecanum wheel

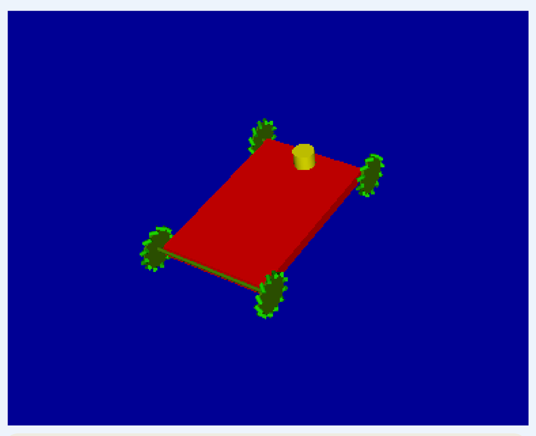
Electronic Design

- compactRIO: real-time embedded industrial controller made by National Instruments,
- ESCON Servo Controller 50/5: equipped with a PI regulator and an auto tuning functionality,
- Xsens MTi: Inertial which contains accelerometer, gyroscope, magnetometer.

NI compactRIO

Software Design

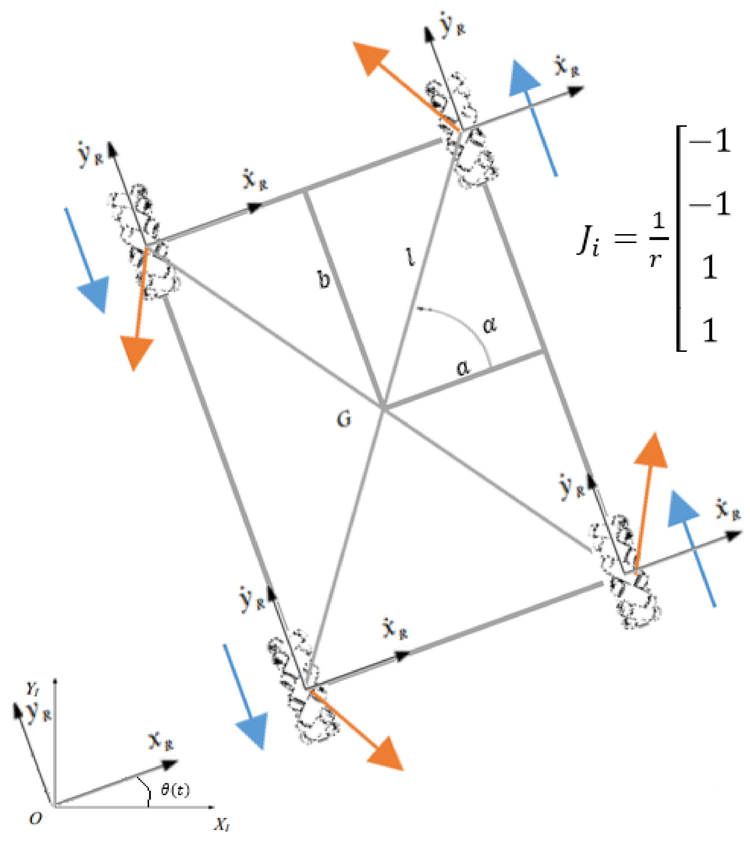
- MATLAB/Simulink: simulation of the inverse and the forward kinematic model and the trajectory tracking,
- LabVIEW Robotics: 3D simulation of the robot motion,
- LabVIEW Real Time implementation of signal processing into the compactRIO.



3D simulation

Methods and Results

Kinematics Modeling

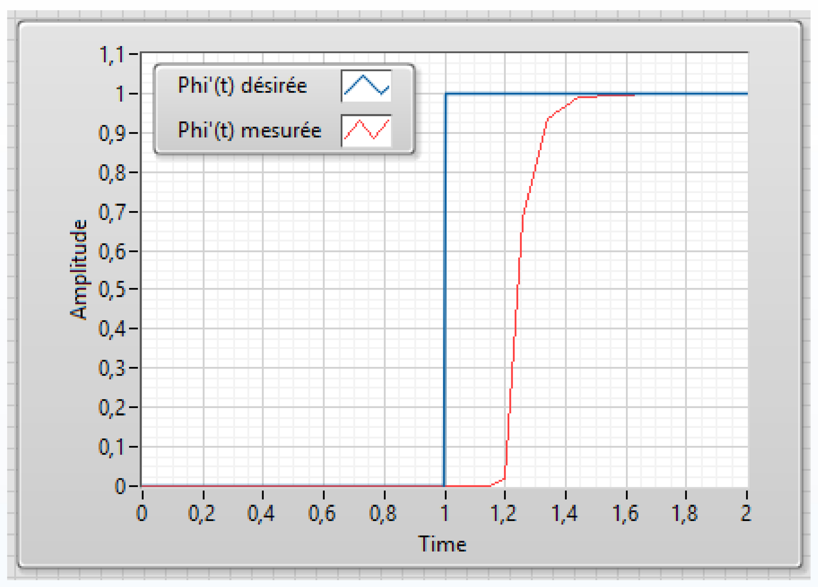


Schematic of the Mecanum robot

$$J_i = \frac{1}{r}\begin{bmatrix} -1 & 1 & l\sqrt{2}\cos(\frac{\pi}{4}-\alpha) \\ -1 & -1 & l\sqrt{2}\cos(\frac{\pi}{4}-\alpha) \\ 1 & -1 & l\sqrt{2}\cos(\frac{\pi}{4}-\alpha) \\ 1 & 1 & l\sqrt{2}\cos(\frac{\pi}{4}-\alpha) \end{bmatrix} \cdot \begin{bmatrix} \cos(\theta(t)) & \sin(\theta(t)) & 0 \\ -\sin(\theta(t)) & \cos(\theta(t)) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Assume that the contact point between the Mecanum wheel and the floor is in a pure rolling condition without slipping, we define above the Jacobian matrix.

System response identifying



System step response.

Using LabVIEW , we plot the step response of the system.

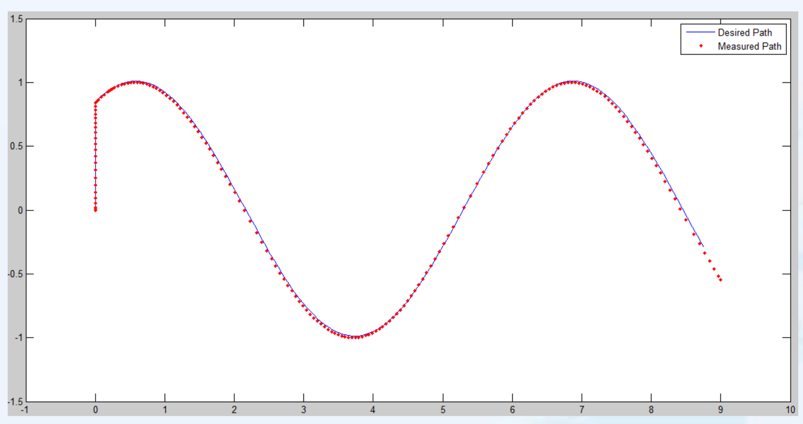
Assume we have a first order system with delay, we get:

$$\frac{\dot{\varphi}^{mesurée}(p)}{\dot{\varphi}^{désirée}(p)} = \frac{e^{-0.2p}}{1+0.05p}$$

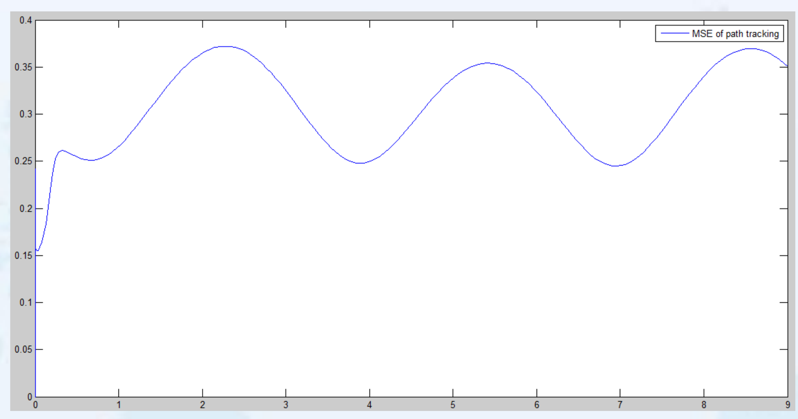
Path tracking

Using MATLAB/Simulink, we simulate the path tracking of the trajectory below:

$$x(t) = \begin{cases} 0 & si\ t < 1 \\ t & si\ t \geq 1 \end{cases} \quad y(t) = \begin{cases} 0 & si\ t < 0 \\ \sin(t) & si\ t \geq 0 \end{cases} \quad \theta(t) = 0 \quad \forall t$$



Desired and measured trajectory



Mean squared error of path tracking

Data fusion

The dead-reckoning method using rotary encoders depends on friction of ground surface and it has an accumulative error.
We estimate the position of the vehicle by fusing odometry and inertial dead-reckoning method based on Kalman filter technique as below:

$$\begin{cases} \dot{\theta}(t) = 0.\theta(t) + B \begin{pmatrix} \dot{\varphi}_1{}^{mesuré}(t) \\ \dot{\varphi}_2{}^{mesuré}(t) \\ \dot{\varphi}_3{}^{mesuré}(t) \\ \dot{\varphi}_4{}^{mesuré}(t) \end{pmatrix} + W \\ \theta^{mesuré} = 1 \,.\, \theta(t) + V \end{cases}$$

Where

$\dot{\varphi}_i{}^{mesuré}(t)$, $i = \{1,2,3,4\}$ angular velocity of each wheel measured by the encoder,

$\theta^{mesuré}(t)$ robot orientation measured by the inertial,

$B = \frac{r}{4l\sqrt{2}\cos(\frac{\pi}{4}-\alpha)}\begin{pmatrix} 1 & 1 & 1 & 1 \end{pmatrix}$ input matrix,

W : state noise

V : measurement noise.

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