FP2: Torso Pose Estimation on the HRP4 Humanoid Robot

Michele Cipriano, Godwin K. Peprah, Lorenzo Vianello

Supervisor: Nicola Scianca
Professors: Giuseppe Oriolo, Alessandro De Luca

Autonomous and Mobile Robotics, Robotics 2
Department of Computer, Control and Management Engineering
Sapienza University of Rome

Introduction

Intro.

Kinematic Model

Todo.

Extended Kalman Filter

Todo.

Accelerometer Integration

Todo.

Gyroscope Integration

Todo.

IMU

Experiments (5.1).

Filtering Linear Velocities

Todo.

Trilateration

Todo.

MPC Loop Closure

Todo.

Regulation

Kinematic Model of the Unicycle

Brief description:

$$\dot{x} = v\cos(\theta)$$
$$\dot{y} = v\sin(\theta)$$
$$\dot{\theta} = \omega$$

with v and ω respectively linear and angular velocity.

Proportional Controller

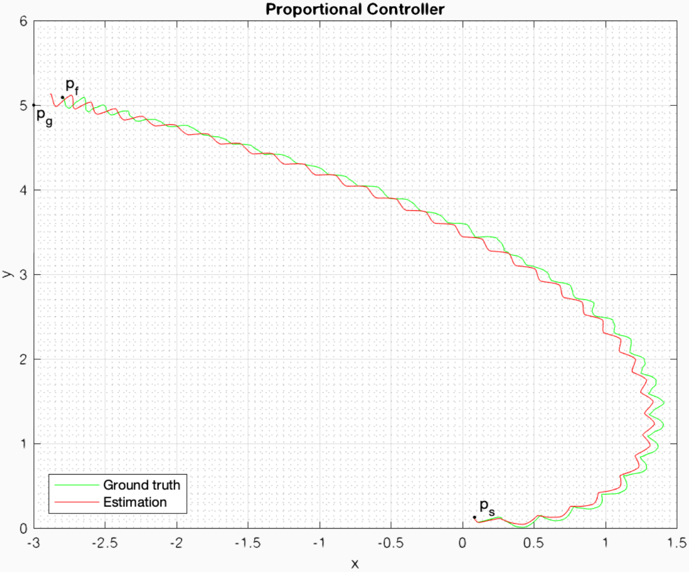
Control law:

$$
\begin{aligned}
v &= k_1 \left\| \boldsymbol{p}_g - \hat{\boldsymbol{p}}_t \right\| \\
\omega &= k_2 e_\theta
\end{aligned}
$$

with e_θ angle between the sagittal vector of the unicycle and the vector pointing from the unicycle towards the goal, $k_1 = 0.18$ and $k_2 = 0.014$. Forcing v and ω to zero when $\left\| \boldsymbol{p}_g - \hat{\boldsymbol{p}}_t \right\| < 0.25$. Desired and final configuration:

$$
\begin{aligned}
\boldsymbol{q}_g &= (-3, 5, \cdot)^T \\
\boldsymbol{q}_f &= (-2.798, 5.090, 0.98\pi)^T \\
\hat{\boldsymbol{q}}_f &= (-2.885, 5.127, 0.979\pi)^T
\end{aligned}
$$

Proportional Controller: x-y Plot



Cartesian Regulation

Let's express the coordinates of the unicycle in a reference frame $\mathcal{F}_g$ fixed at a position $(x_g, y_g)^T$ and rotated by θ_g around $\mathcal{F}_w$:

$$\begin{pmatrix} {}^g x \\ {}^g y \\ {}^g \theta \end{pmatrix} = \boldsymbol{R}_z^T(\theta_g) \begin{pmatrix} x - x_g \\ y - y_g \\ \theta - \theta_g \end{pmatrix}$$

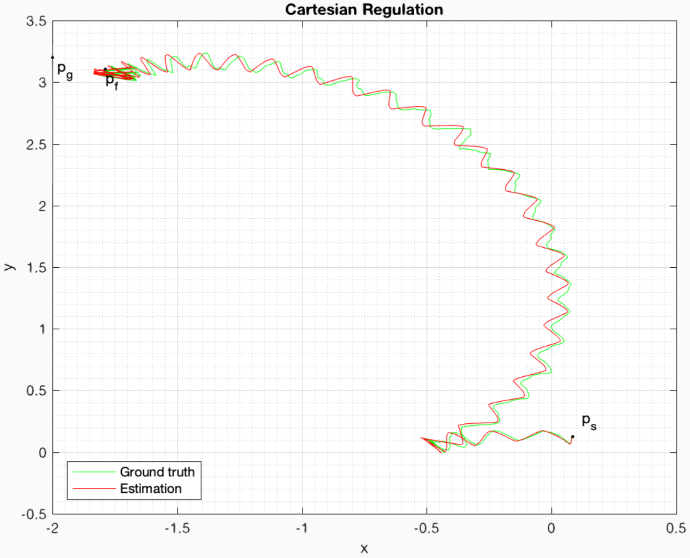
Control law:

$$v = -k_1({}^g x \cos({}^g\theta) + {}^g y \sin({}^g\theta))$$
$$\omega = k_2(\mathrm{Atan2}({}^g y, {}^g x) - {}^g\theta + \pi)$$

with $k_1 = 0.07$ and $k_2 = 0.01$. Forcing v and ω to zero when $\|\boldsymbol{p}_g - \hat{\boldsymbol{p}}_t\| < 0.2$. Desired and final configuration:

$$\boldsymbol{q}_g = (-2, 3.2, \cdot)^T$$
$$\boldsymbol{q}_f = (-1.788, 3.105, 1.562\pi)^T$$
$$\hat{\boldsymbol{q}}_f = (-1.823, 3.108, 1.562\pi)^T$$

Cartesian Regulation: x-y Plot



Kinematic Model of the Unicycle in Polar Coordinates

Brief description:

$$\dot{\rho}_r = -v\cos(\gamma_r)$$
$$\dot{\gamma}_r = \frac{\sin(\gamma_r)}{\rho_r}v - \omega$$
$$\dot{\delta}_r = \frac{\sin(\gamma_r)}{\rho_r}v$$

Polar coordinates can be obtained from the generalized coordinates of the unicycle $(x, y, \theta)^T$ by computing:

$$\rho_r = \sqrt{{}^g x^2 + {}^g y^2}$$
$$\gamma_r = \mathrm{Atan2}({}^g y, {}^g x) - {}^g\theta + \pi$$
$$\delta_r = \gamma_r + {}^g\theta$$

Posture Regulation

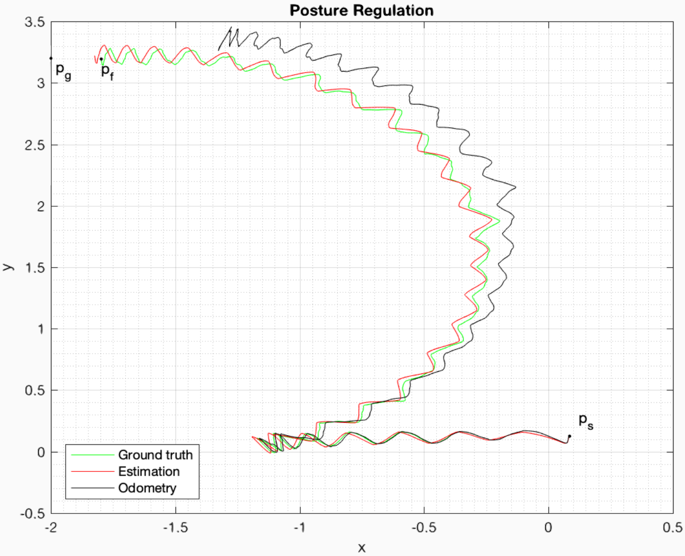
Control law:

$$v = k_1 \rho_r \cos(\gamma_r)$$
$$w = k_2 \gamma_r + k_1 \frac{\sin(\gamma_r)\cos(\gamma_r)}{\gamma_r}(\gamma_r + k_3 \delta_r)$$

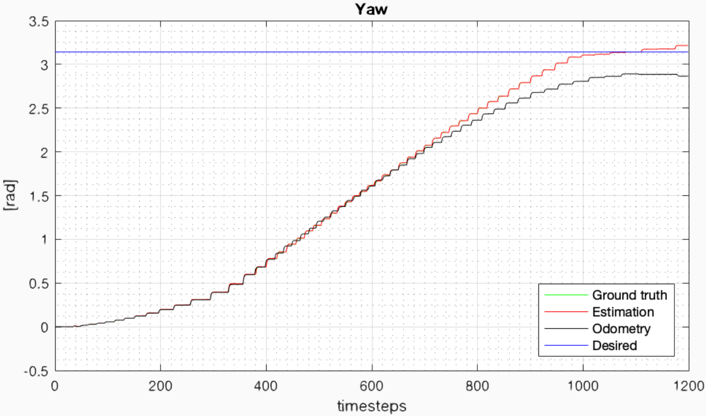
with $k_1 = 0.1$, $k_2 = 0.007$ $k_3 = 0.004$. Forcing v and ω to zero when $\rho_r < 0.2$. Desired and final configuration:

$$\boldsymbol{q}_g = (-2, 3.2, \pi)^T$$
$$\boldsymbol{q}_f = (-1.797, 3.194, 1.024\pi)^T$$
$$\hat{\boldsymbol{q}}_f = (-1.824, 3.222, 1.024\pi)^T$$
$$\bar{\boldsymbol{q}}_f = (-1.282, 3.424, 0.912\pi)^T$$

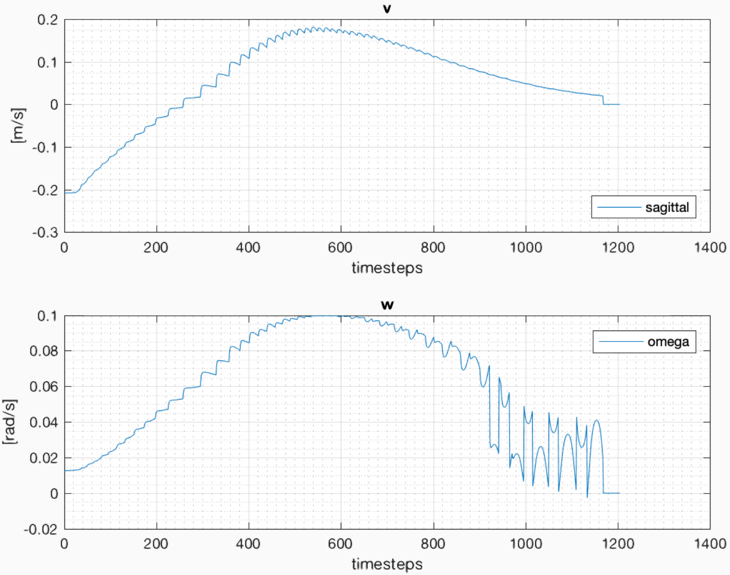
Posture Regulation: x-y Plot



Posture Regulation: Yaw Plot



Posture Regulation: Velocity Profile Plots



Conclusion

Conclusion.

Q&A

References

- G. Oriolo, A. Paolillo, L. Rosa, and M. Vendittelli, “Humanoid odometric localization integrating kinematic, inertial and visual information,” *Auton. Robots*, vol. 40, no. 5, pp. 867–879, 2016.
- W. Hereman and J. William S. Murphy, “Determination of a Position in Three Dimensions Using Trilateration and Approximate Distances,” 1995.
- B. Siciliano, L. Sciavicco, L. Villani, and G. Oriolo, *Robotics: Modelling, Planning and Control*. Springer Publishing Company, Incorporated, 1st ed., 2008.