encoder provides 1024 pulses per revolution and each revolution of the wheel generates a revolution of the encoder (1:1 coupling). Wheel rotation is transferred to encoders through a flexible mechanical transmission system that goes from the center of each wheel to the encoder placed on the side of the vehicle (see Figure 1). Encoder output is connected to an ad hoc electronics that samples the encoders signal every 0.5 ms. The electronics is designed to measure and integrate the encoder signals and the output is transmitted to the on-board computer every integration period of 20 ms. The integration is made in the microcontroller installed in the ad hoc electronics, based on Euler integration, collecting encoder increments for the integration time.

Kinematic state of the cart (pose) is described by its position (x, y) with respect to a fixed reference system and its orientation θ (angle between X axis of reference system and the cart longitudinal position).

When the prototype is turning, a circular trajectory is followed. The integration time is small enough to consider the trajectory curvature as constant. In Figure 2, initial (x_i, y_i) and final (x_f, y_f) position after and integration time are shown. Rear wheels displacements are obtained from the encoders and wheel size.

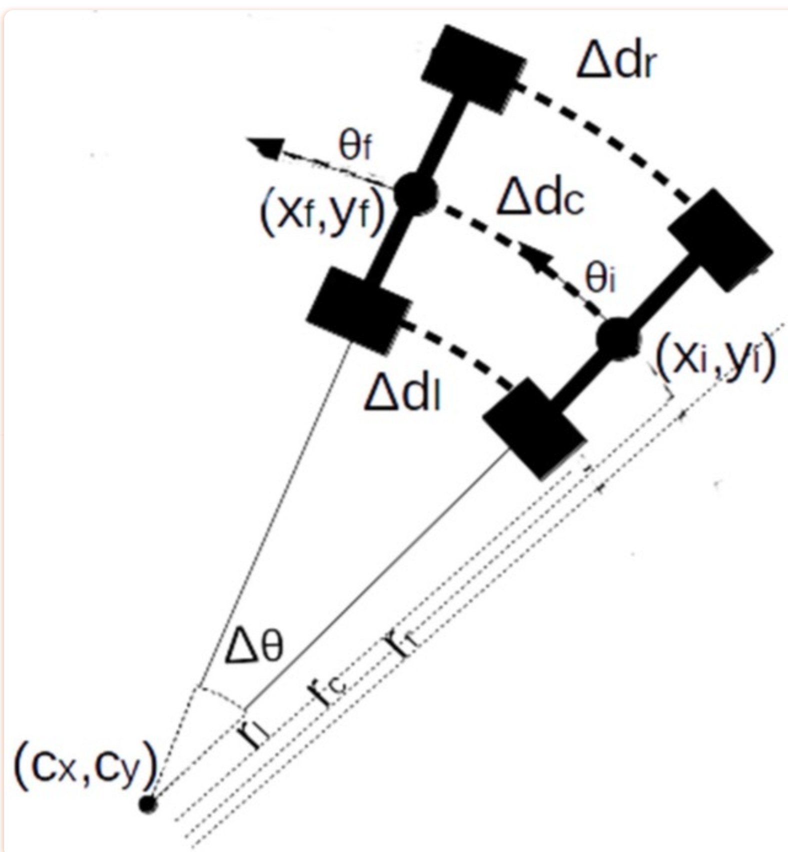

Figure 2

Odometric model.

The arc length of right (Δ_{dr}) and left (Δ_{dl}) rear wheels can be calculated based on encoder measurement (Δ_{cr}, Δ_{cl}), wheel radius (R_r, R_l), and encoder resolution (Enc_r, Enc_l).

$$\begin{aligned} \Delta d_r &= \frac{2\pi R_r \Delta c_r}{Enc_r} \\ \Delta d_l &= \frac{2\pi R_l \Delta c_l}{Enc_l} \end{aligned} \tag{1}$$

Curvature radius for each wheel and center is calculated based on wheel distance d_w.

$$\begin{aligned} r_r &= \frac{\Delta d_r d_w}{\Delta d_r - \Delta d_l} \\ r_l &= \frac{\Delta l_r d_w}{\Delta d_r - \Delta d_l} \\ r_c &= \frac{d_w}{2} \frac{\Delta d_r + \Delta d_l}{\Delta d_r - \Delta d_l} \end{aligned} \tag{2}$$

With these assumptions, angle Δ_θ and position (Δ_x, Δ_y) increments are:

$$\begin{aligned} \Delta_\theta &= \frac{\Delta d_r - \Delta d_l}{d_w} \\ \Delta_x &= r_c \left(\cos(\theta) \sin(\Delta_\theta) - \sin(\theta)\left(1 - \cos(\Delta_\theta)\right)\right) \\ \Delta_y &= r_c \left(\sin(\theta) \sin(\Delta_\theta) + \cos(\theta)\left(1 - \cos(\Delta_\theta)\right)\right) \end{aligned} \tag{3}$$

and in the last step, position and orientation are updated with the last computed increments:

$$\begin{aligned} \theta_{i+1} &= \Delta_\theta + \theta_i \\ x_{i+1} &= \Delta_x + x_i \\ y_{i+1} &= \Delta_y + y_i \end{aligned} \tag{4}$$

Feedback

The odometry model only depends on three free parameters, wheel radiuses (R_r, R_l) and wheel separation d_w. According to this model, the only step to tune the odometric system is to measure these parameters as accurately as possible.

3. Odometric Validation