Drive System Selection and Operational Justification

Drive System Selection and Justification

In the context of mobile robotic platforms, selecting an appropriate drive system is critical to ensure accurate navigation, controlled maneuvering, and sufficient mechanical capability. Among the drive configurations—X Omni-Wheel Drive, Kiwi Omni-Wheel Drive, Differential Drive, and Mecanum Wheel Drive—this study identifies the Mecanum Wheel Drive as the most suitable for addressing the forward drift, angular overshoot, and dynamic load handling.

1. Forward Drift During Linear Motion

A recurrent issue observed in holonomic drive systems, especially those employing omni-wheels, is unintended lateral drift during translational motion. This phenomenon primarily arises due to asymmetric motor output, frame imbalance, or insufficient traction between rollers and the surface. Mecanum wheels, by virtue of their helical roller alignment and increased surface engagement, provide improved lateral force stability. When integrated with feedback control mechanisms such as PID loops and encoder-based velocity correction, the Mecanum configuration effectively mitigates drift, enabling reliable point-to-point linear traversal.

2. Overshooting in Angular Maneuvers

Overshoot during rotational maneuvers, particularly 90° turns, is indicative of underdamped system dynamics or inadequate deceleration strategies. Unlike differential drives, which require a pivoting action and often lack fine-grained torque control, Mecanum drives offer independent control over each wheel's velocity and direction. This facilitates pure rotational motion about the robot's centroid. Coupled with inertial measurement units (IMUs) and real-time feedback control, the platform achieves high-precision angular alignment without residual overshoot.

3. Load Handling and Force Application

The ability to exert force against external loads, such as pushing containers, is contingent upon wheel-ground friction and the directional efficiency of motor force vectors. Differential drives, while strong in unidirectional pushing, lack lateral flexibility. Omni-wheels often underperform due to roller-induced slippage. In contrast, Mecanum wheels enable vectorized force synthesis, allowing all four wheels to generate forward thrust simultaneously. The configuration not only supports multi-directional movement but also ensures robust force delivery when operating against static or dynamic loads.

Conclusion

Considering the above analyses, the Mecanum Wheel Drive emerges as the optimal choice.

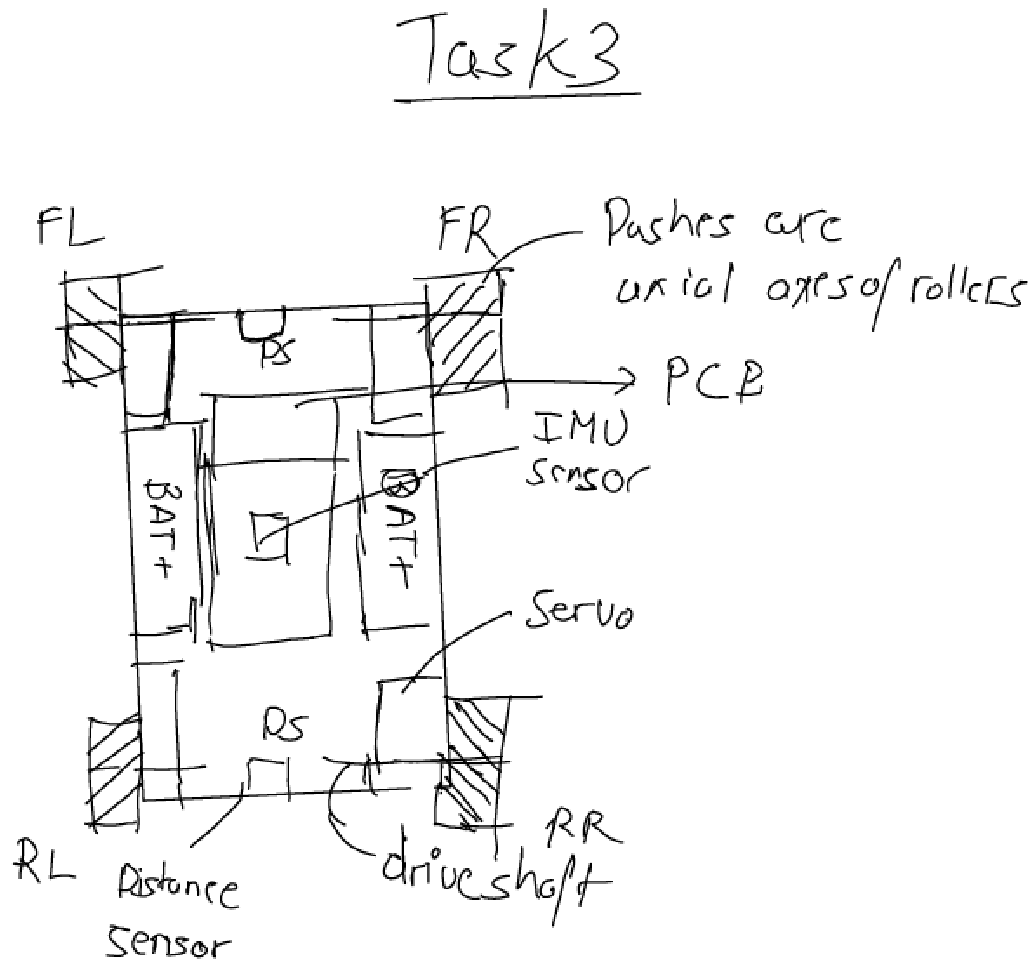

Figure 1: believe me i am not used to digital art yet

Wheel Placement

- Front Left (FL): Wheel 1 - Front Right (FR): Wheel 2 - Rear Left (RL): Wheel 3 - Rear Right (RR): Wheel 4

Parameters

- r : radius of each wheel
- l_x : half of the robot width
- l_y : half of the robot length
- ω_i : angular velocity of wheel i (1 to 4)
- v_x, v_y : linear velocities of the robot in the body frame
- ω_z : angular velocity (yaw rate) of the robot

3. Forward Kinematics

To find each wheel speed ω_i required to achieve a desired motion (v_x, v_y, ω_z):

Wheel 1 (Front Left)

$$\omega_1 = \frac{1}{r}(v_x - v_y - (l_x + l_y)\omega_z)$$

Wheel 2 (Front Right)

$$\omega_2 = \frac{1}{r}(v_x + v_y + (l_x + l_y)\omega_z)$$

Wheel 3 (Rear Left)

$$\omega_3 = \frac{1}{r}(v_x + v_y - (l_x + l_y)\omega_z)$$

Wheel 4 (Rear Right)

$$\omega_4 = \frac{1}{r}(v_x - v_y + (l_x + l_y)\omega_z)$$

4. Inverse Kinematics

To compute the robot's chassis velocities from wheel speeds:

Forward Velocity (v_x)

$$v_x = \frac{r}{4}(\omega_1 + \omega_2 + \omega_3 + \omega_4)$$

Lateral Velocity (v_y)

$$v_y = \frac{r}{4}(-\omega_1 + \omega_2 + \omega_3 - \omega_4)$$

Rotational Velocity (ω_z)

$$\omega_z = \frac{r}{4(l_x + l_y)}(-\omega_1 + \omega_2 - \omega_3 + \omega_4)$$

5. Dynamic Equations

The dynamics of the robot's movement can be modeled using Newton's laws.

Translational Dynamics

$$M\frac{dv_x}{dt} = F_x - f_{r,x}$$

$$M\frac{dv_y}{dt} = F_y - f_{r,y}$$

Rotational Dynamics

$$J\frac{d\omega_z}{dt} = \tau_z - \tau_r$$

Where:

- M is the mass of the robot,
- J is the moment of inertia about the z-axis,
- F_x, F_y are the net forces in the x and y directions,
- $f_{r,x}$, $f_{r,y}$ are resistive/friction forces,
- τ_z is the net torque generated by the wheels,
- τ_r is resistive torque (e.g., from friction or drag).