Coaxial Swerve Drivetrain
How a Coaxial drivetrain works in an in depth explanation.

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Preface

A coaxial swerve drive is a type of drivetrain commonly used in robotics. It consists of two swerve drives, one on top of the other, with the top swerve drive offset from the bottom swerve drive. This configuration allows for greater stability and flexibility in motion control.

In this paper, we will discuss the kinematics and odometry of a coaxial swerve drive, including the kinematics for an individual swerve drive and the kinematics for the entire swerve drive.

Chapter 1

Individual Swerve Drive Kinematics

An individual swerve drive consists of a wheel that can rotate about its vertical axis and pivot about a point at the center of the wheel. This allows the robot to move in any direction without changing its orientation.

The kinematics of an individual swerve drive can be described using the following equations:

$$\begin{bmatrix} v_x \ v_y \ \omega \end{bmatrix} \begin{bmatrix} \cos\theta & -\sin\theta & r \ \sin\theta & \cos\theta & 0 \ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \dot{x} \ \dot{y} \ \dot{\theta} \end{bmatrix}$$

where v_x and v_y are the linear velocities in the x and y directions, ω is the angular velocity, θ is the orientation of the wheel, r is the distance from the center of the wheel to the pivot point, and $\dot{x}$, $\dot{y}$, and $\dot{\theta}$ are the velocities of the wheel in the x, y, and θ directions, respectively.

Chapter 2

Coaxial Swerve Drive Kinematics

The kinematics of a coaxial swerve drive can be described using the following equations:

$$\begin{bmatrix} v_{1x} \; v_{1y} \; \omega_1 \end{bmatrix} \begin{bmatrix} \cos\theta_1 & -\sin\theta_1 & r_1 \; \sin\theta_1 & \cos\theta_1 & 0 \; 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \dot{x} \; \dot{y} \; \dot{\theta} \end{bmatrix}$$

$$\begin{bmatrix} v_{2x} \; v_{2y} \; \omega_2 \end{bmatrix} \begin{bmatrix} \cos\theta_2 & -\sin\theta_2 & r_2 \; \sin\theta_2 & \cos\theta_2 & 0 \; 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \dot{x} \; \dot{y} \; \dot{\theta} \end{bmatrix}$$

where v_{1x} and v_{1y} are the linear velocities in the x and y directions of the bottom swerve drive, $\$v_{2x}$ and v_{2y} are the linear velocities in the x and y directions of the top swerve drive, ω_1 and ω_2 are the angular velocities of the bottom and top swerve drives, θ_1 and θ_2 are the orientations of the bottom and top wheels, r_1 and r_2 are the distances from the centers of the bottom and top wheels to their respective pivot points, and $\dot{x}$, $\dot{y}$, and $\dot{\theta}$ are the velocities of the robot in the x, y, and θ directions, respectively.

The total linear and angular velocities of the robot can be calculated as follows:

$$\begin{bmatrix} v_x \; v_y \; \omega \end{bmatrix} \frac{1}{2} \begin{bmatrix} 1 & 1 \; 0 & 0 \; 1 & -1 \end{bmatrix} \begin{bmatrix} v_{1x} \; v_{1y} \; \omega_1 \; v_{2x} \; v_{2y} \; \omega_2 \end{bmatrix}$$

where v_x and v_y are the linear velocities of the robot in the x and y directions, and ω is the angular velocity of the robot.

Chapter 3

Odometry

To calculate the odometry of the coaxial swerve drive, we can use the following equations:

$$\begin{bmatrix}\Delta x \ \Delta y \ \Delta\theta\end{bmatrix} \begin{bmatrix}\cos\theta & \sin\theta & 0 - \sin\theta & \cos\theta & 0\,0 & 0 & 1\end{bmatrix} \begin{bmatrix}\Delta x_1 \ \Delta y_1 \ \Delta\theta_1\end{bmatrix}$$

$$\begin{bmatrix}\Delta x_1 \ \Delta y_1 \ \Delta\theta_1\end{bmatrix} \begin{bmatrix}\frac{1}{2} & \frac{1}{2} & \frac{l}{2}\,0 & 0 & \frac{w}{2}\,\frac{1}{2l} & -\frac{1}{2l} & \frac{1}{w}\end{bmatrix} \begin{bmatrix}\Delta\phi_1 \ \Delta\phi_2 \ \Delta\phi_3\end{bmatrix}$$

where Δx, Δy, and $\Delta\theta$ are the change in position and orientation of the robot, θ is the orientation of the robot, l is the distance between the centers of the bottom and top swerve drives, w is the distance between the centers of the left and right wheels on each swerve drive, Δx_1, Δy_1, and $\Delta\theta_1$ are the change in position and orientation of the bottom swerve drive, $\Delta\phi_1$, $\Delta\phi_2$, and $\Delta\phi_3$ are the changes in the angle of each wheel on the bottom swerve drive.

The changes in wheel angles can be calculated using the following equations:

$$\Delta\phi_1 = \frac{1}{r}\left(v_{1x}\cos\theta_1 + v_{1y}\sin\theta_1 - r_1\omega_1\right)\ \Delta\phi_2 \quad = \frac{1}{r}\left(-v_{1x}\cos\theta_1 + v_{1y}\sin\theta_1 - r_1\omega_1\right)\ \Delta\phi_3 = \frac{1}{r}\left(v_{2x}\cos\theta_2 + v_{2y}\sin\theta_2 - r_2\omega_2\right)$$

where r is the radius of the wheels.

Using these equations, we can calculate the odometry of the coaxial swerve drive and use it for localization and path planning.

Chapter 4

Conclusion

In this document, we have discussed the kinematics and odometry of a coaxial swerve drive. A coaxial swerve drive is a complex mechanism that requires careful consideration of the kinematics and dynamics involved. The equations and formulas presented in this document provide a solid foundation for designing, building, and controlling a coaxial swerve drive. By understanding the kinematics and dynamics of a coaxial swerve drive, we can develop efficient and effective control strategies that enable the robot to move with precision and accuracy.

Chapter 5

References

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