Scientific Experimentation and Evaluation
Assignment 1.1

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Deliverables 1.1

Experimental setup

- **Measurement system**: Our measurement system would consist of robot placed on a paper sheet as floor. We would need to attach a marker such as pencil on robot which would trace the path traversed by the robot on the paper. Additionally we would mark the wheel positions both at the start and end of a trial to measure the change in pose of robot.
- **Measurand**: The physical quantity we'll be measuring will be the displacement length from initial position of robot to the end pose of robot traversed on the paper sheet.
- **Measured quantity**: The variable to be measured is the change in pose from start pose (x, y, θ) to the end pose (x', y', θ') given by,

$$\begin{aligned}\delta x = x' - x &= \delta_{\text{trans}} \cos(\theta + \delta_{\text{rot1}}) \\ \delta y = y' - y &= \delta_{\text{trans}} \sin(\theta + \delta_{\text{rot1}}) \\ \delta\theta = \theta' - \theta &= \text{rot1} + \text{rot1}\end{aligned}$$

Expected problems

- **Systematic errors**[1]: Systematic errors are caused by difference in the theoretical model and actual design of the robot such as, in our case, unequal wheel diameters (E_D) and uncertainty about effective wheelbase(E_B) would create a systematic error in expected distance travelled (theoretical model, $\delta_{\text{trans-th}}$) and actual distance travelled (δ_{trans}). These errors are robot specific don't change for a robot. Thus these errors can be improved upon by measuring their individual contributions and counter-acting their effects in software.
The error in wheel diameter can be defined as ratio between two wheel diameters,

$$E_D = \frac{D_R}{D_L}$$

where D_R and D_L are actual right and left wheel diameters respectively. Error in wheel diameter affects the straight line motion whereas error in wheelbase affects the turning of the robot. The error in wheelbase is given as,

$$E_B = \frac{b_{\text{actual}}}{b_{\text{assumed}}}$$

where b_{actual} is the actual length of wheelbase and b_{assumed} is the length of wheelbase assumed by software.

- **Random errors**: Random errors are caused by inability of the sensors to measure the input beyond certain resolution. In our case inability to resolve current supplied beyond certain resolution would result in slight deviations in torques torques generated in motor which results in wheel rotation and ultimately results in variations in distance travelled by robot. We can correct this error by repeating the experiment multiple number of times and taking the mean value of

[1] Partial explanation of systematic error is derived from http://www-personal.umich.edu/~johannb/Papers/paper59.pdf.

the measurements. The mean value of change of pose can be given as,

$$\overline{\delta x} = \frac{1}{20}\sum_{i=1}^{20} \delta x_i$$
$$\overline{\delta y} = \frac{1}{20}\sum_{i=1}^{20} \delta y_i$$
$$\overline{\delta \theta} = \frac{1}{20}\sum_{i=1}^{20} \delta \theta_i$$

The standard error of the mean for each variable is given by,

$$\hat{\sigma}_{\overline{\delta x}} = \sqrt{\frac{\sum_{i=1}^{20}(\delta x - \overline{\delta x})^2}{19 * 20}}$$
$$\hat{\sigma}_{\overline{\delta y}} = \sqrt{\frac{\sum_{i=1}^{20}(\delta y - \overline{\delta y})^2}{19 * 20}}$$
$$\hat{\sigma}_{\overline{\delta \theta}} = \sqrt{\frac{\sum_{i=1}^{20}(\delta \theta - \overline{\delta \theta})^2}{19 * 20}}$$

Expected performance

- The uncertainty in pose due to random errors for each trial can be given as,

$$\delta x = \delta x_{\text{measured}} \pm \hat{\sigma}_{\overline{\delta x}}$$
$$\delta y = \delta y_{\text{measured}} \pm \hat{\sigma}_{\overline{\delta y}}$$
$$\delta \theta = \delta \theta_{\text{measured}} \pm \hat{\sigma}_{\overline{\delta \theta}}$$