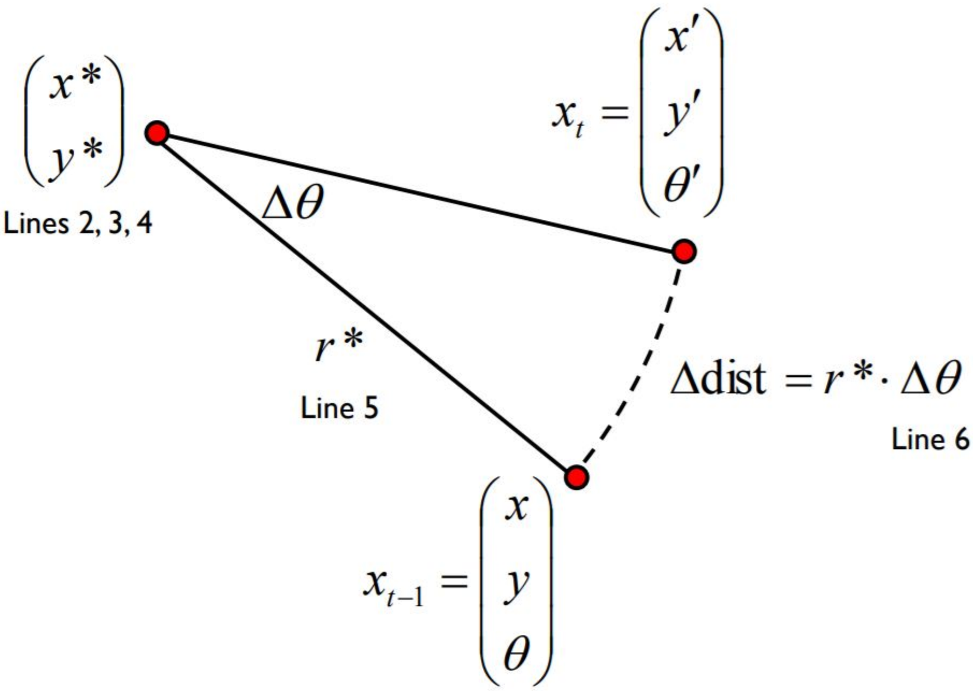
0.1 DEAD RECKONING

Velocity Motion Model(Dead-Reckoning)- Direct Evaluation



1. Compute coordinates of center of rotation

$$
\begin{aligned}
x^\star &= \frac{x+x^{'}}{2} + \mu(y-y^{'}) \\
y^\star &= \frac{y+y^{'}}{2} + \mu(x^{'}-x) \\
where \quad \mu &= \frac{(x-x^{'})\cos\theta + (y-y^{'})\sin\theta}{(y-y^{'})\cos\theta - (x-x^{'})\sin\theta}
\end{aligned}
$$

2. Compute radius

$$
r^\star = \sqrt{(x-x^\star)^2 + (y-y^\star)^2}
$$

3. Compute angle change

$$
\Delta\theta = atan2(y^{'}-y^\star, x^{'}-x^\star) - atan2(y-y^\star, x-y^\star)
$$

4. Compute translational velocity

$$\hat{v} = \frac{\Delta\theta}{\Delta t}$$

5. Compute rotational velocity

$$\hat{\omega} = \frac{\Delta\theta}{\Delta t}$$

6. Compute the difference in between rotational velocities

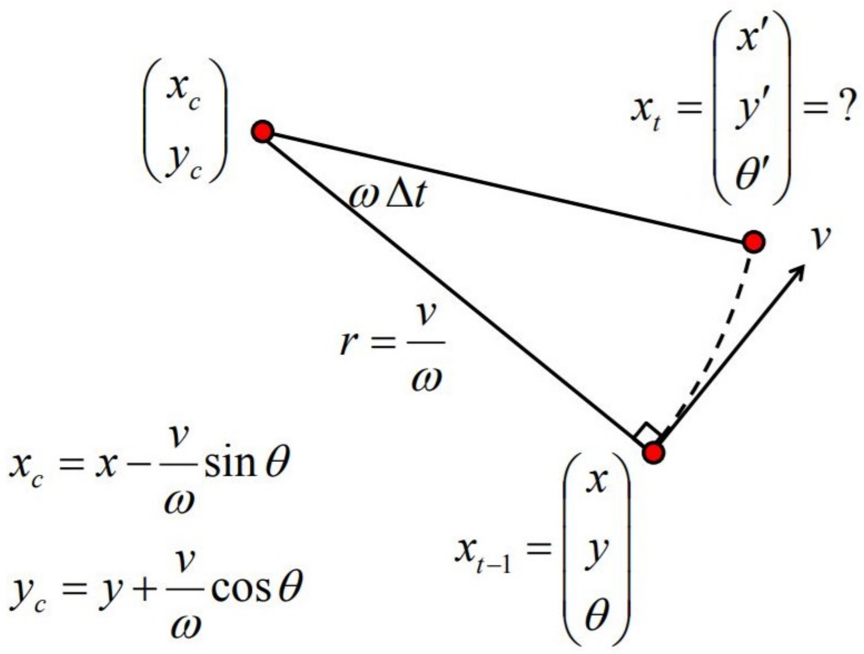
$$\hat{\gamma} = \frac{\theta' - \theta}{\Delta t} - \hat{\omega}$$

7. Compute the product of probability densities

$$prob(v - \hat{v}, \alpha_1 \mid \omega \mid + \alpha_2 \mid \omega \mid) * prob(\omega - \hat{\omega}, \alpha_3 \mid v \mid + \alpha_4 \mid \omega \mid) * prob(\hat{\gamma}, \alpha_5 \mid v \mid + \alpha_6 \mid \omega \mid)$$

Velocity Motion Model(Dead-Reckoning)- Direct Evaluation Results

Velocity Motion Model(Dead-Reckoning) - Sampling



2. Compute actual velocity(translational) from commanded velocity(translational)

$$\hat{v} = v + sample(\alpha 1 \mid \omega \mid + \alpha 2 \mid \omega \mid)$$

3. Compute actual velocity(rotational) from commanded velocity(rotational)

$$\hat{\omega} = \omega + sample(\alpha 3 \mid v \mid + \alpha 4 \mid \omega \mid)$$

4. Compute angular velocity of the robot spinning in place

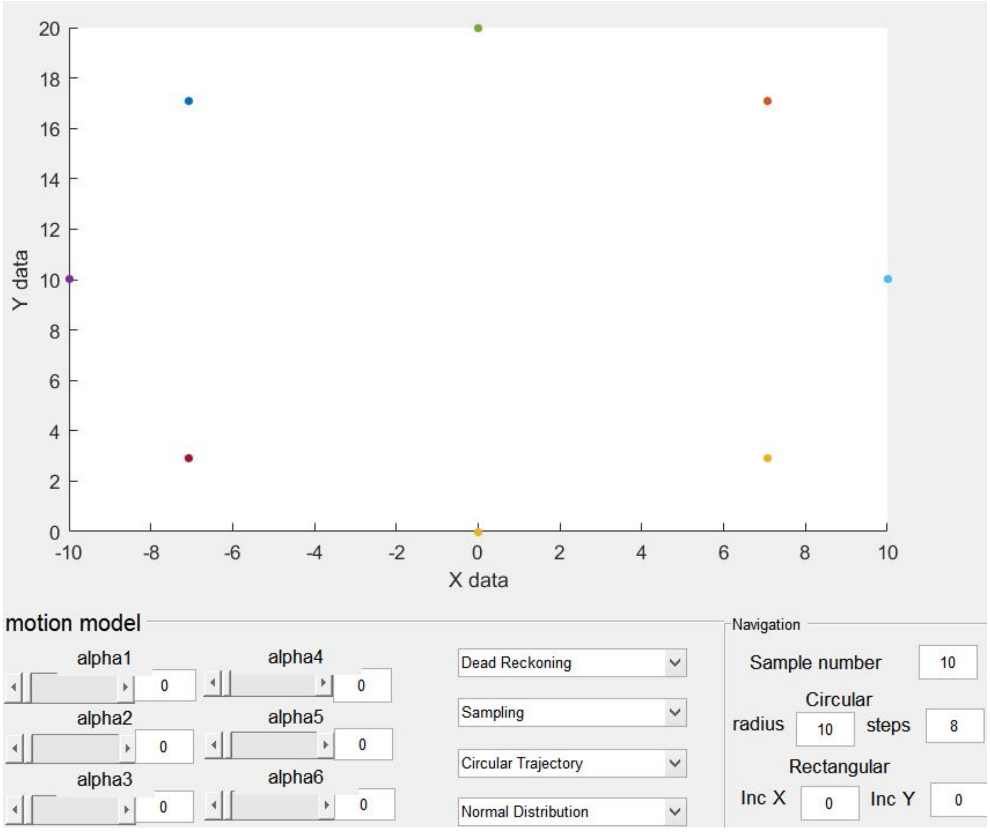
$$\hat{\gamma} = sample(\alpha 5 \mid v \mid + \alpha 6 \mid \omega \mid)$$

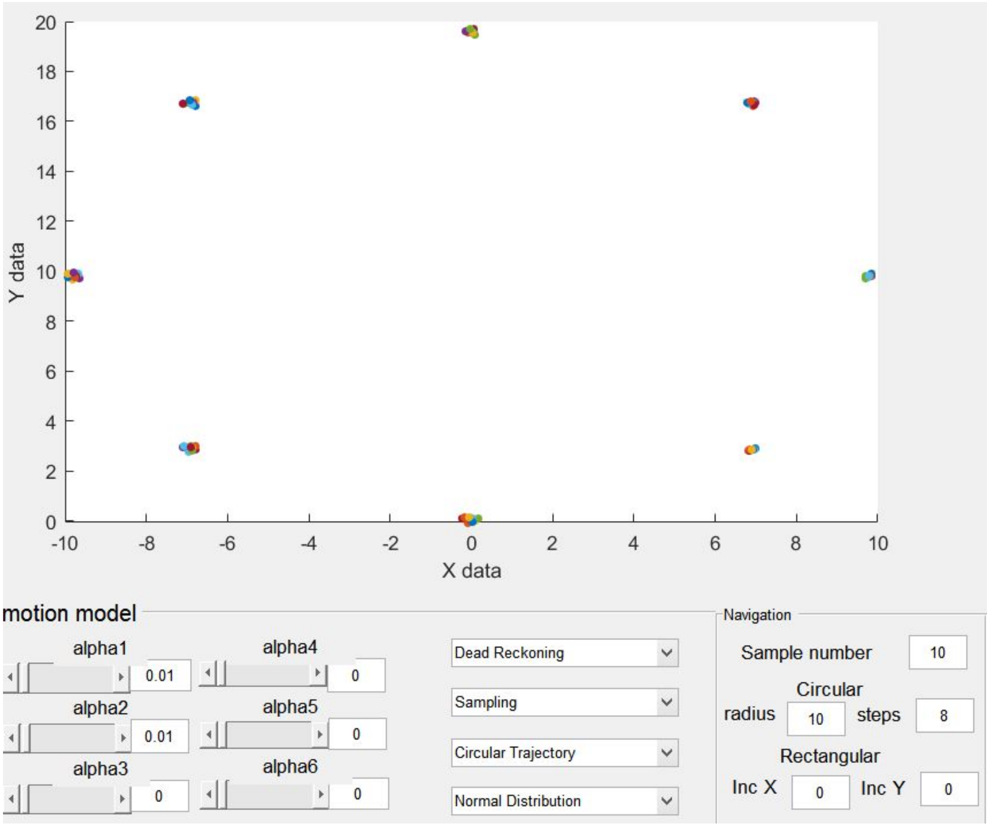
5. Compute state at time t

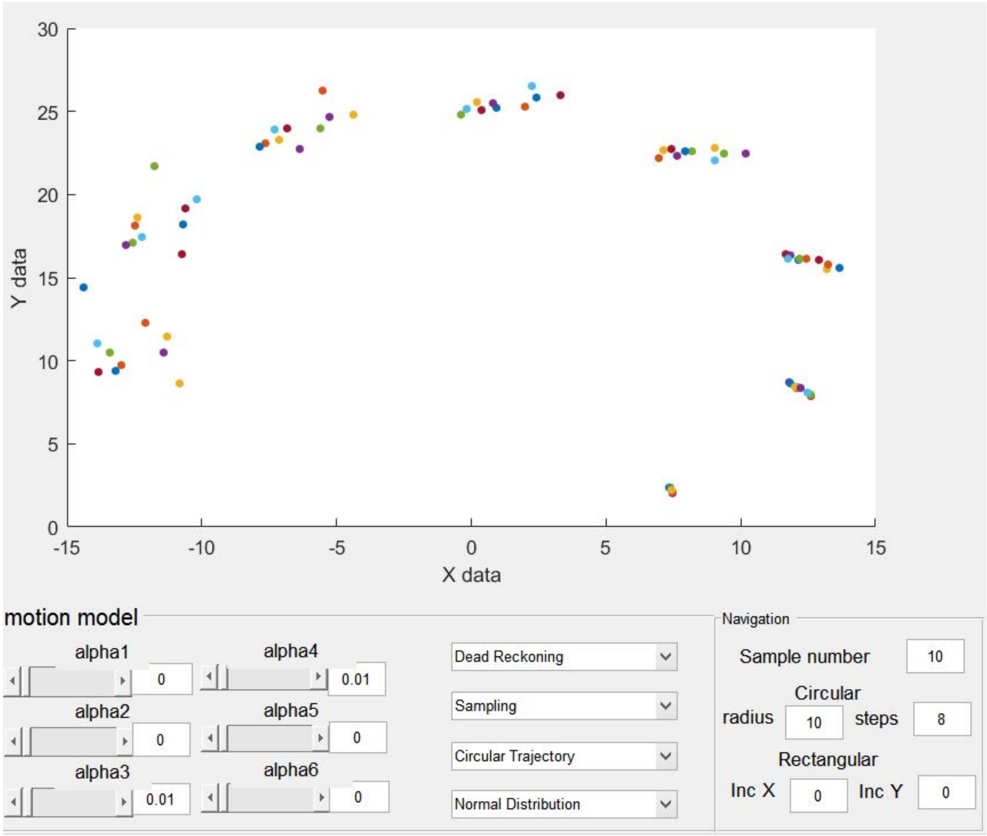
$$\begin{aligned} x' &= x + \frac{\hat{v}}{\hat{\omega}} \sin\theta + \frac{\hat{v}}{\hat{\omega}} \sin(\theta + \hat{\omega}\Delta t) \\ y' &= y + \frac{\hat{v}}{\hat{\omega}} \cos\theta - \frac{\hat{v}}{\hat{\omega}} \cos(\theta + \hat{\omega}\Delta t) \\ \theta' &= \theta + \hat{\omega}\Delta t + \hat{\gamma}\Delta t \end{aligned}$$

Dead Reckoning Sampling Results

With no uncertainty




Y data
X data
motion model
alpha1
alpha2
alpha3
alpha4
alpha5
alpha6
Dead Reckoning
Sampling
Circular Trajectory
Normal Distribution
Navigation
Sample number
Circular
radius
steps
Rectangular
Inc X
Inc Y

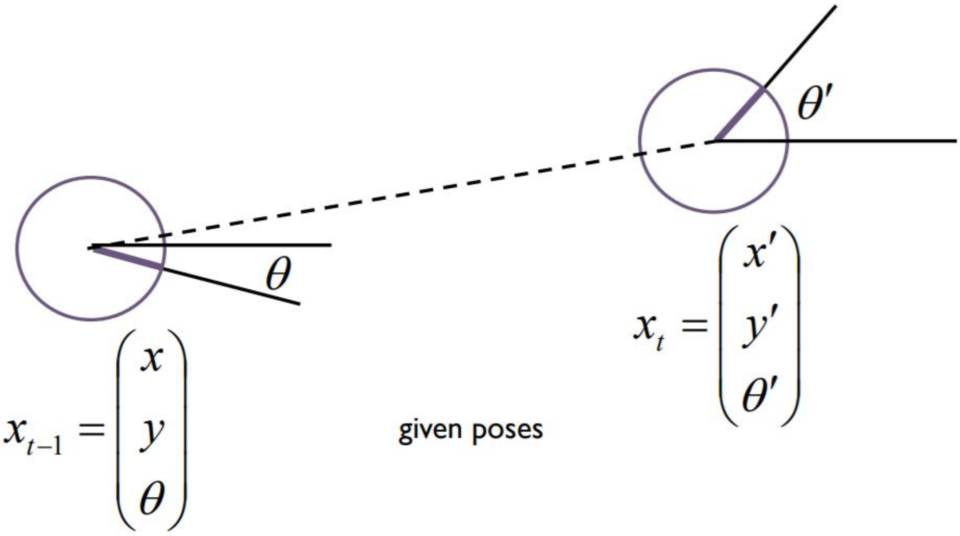

30
25
20
15
10
5
0
-15
-10
-5
0
5
10
15
X data
Y data
motion model
alpha1
0
alpha4
0.01
alpha2
0
alpha5
0
alpha3
0.01
alpha6
0
Dead Reckoning
Sampling
Circular Trajectory
Normal Distribution
Navigation
Sample number
10
Circular
radius
10
steps
8
Rectangular
Inc X
0
Inc Y
0

UKF Main.m

0.2 ODOMETRY

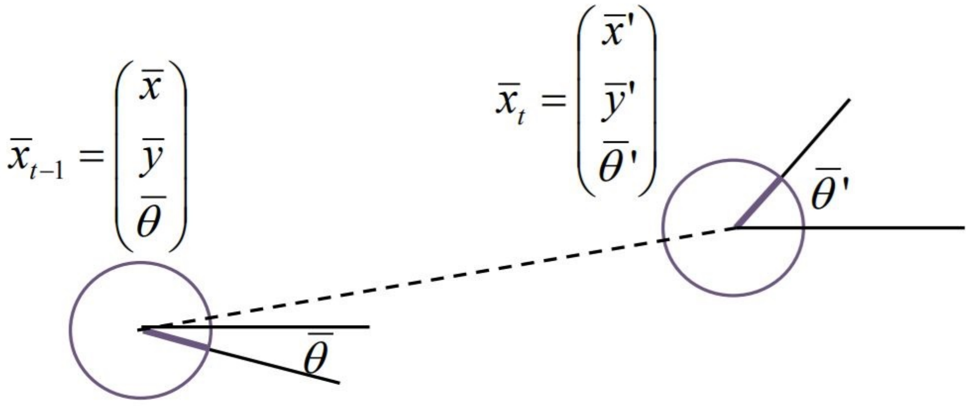
Odometry uses sensors(often rotary encoder) to measure motion to estimate changes in position over time. It typically more accurate than velocity motion model however, measurements are available obly after the motion has been completed.

Odometry Motion Model - Direct Evaluation



Use robot's internal pose estimates to compute the δ

$$\delta_{trans} = \sqrt{(\bar{x}' - \bar{x})^2 + (\bar{y}' - \bar{y})^2}$$
$$\delta_{rot1} = atan2(\bar{y}^{'} - \bar{y}, \bar{x}^{'} - \bar{x}$$
$$\delta_{rot2} = \bar{\theta}^{'} - \bar{\theta} - \delta_{rot1}$$



robot's internal poses

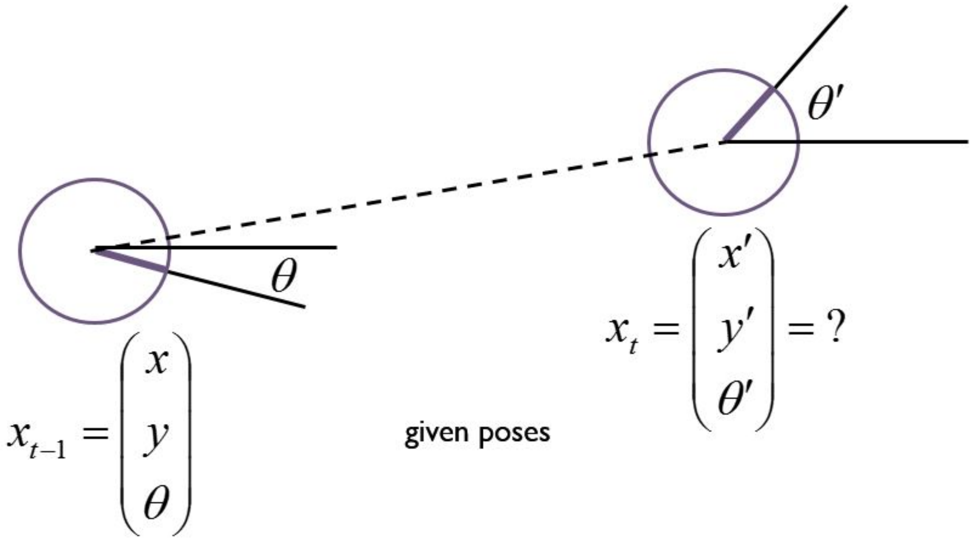
Use the given poses to compute the $\hat{\delta}$

$$\hat{\delta}_{trans} = \sqrt{(x' - x)^2 + (y' - y)^2}$$
$$\hat{\delta}_{rot1} = atan2(y^{'} - y, x^{'} - x$$
$$\hat{\delta}_{rot2} = \theta^{'} - \theta - \delta_{rot1}$$

Compute the product of probability densities

$$\begin{aligned} prob(\delta_{rot1} - \hat{\delta}_{rot1}, \alpha_1 \mid \hat{\delta}_{rot1} \mid + \alpha_2 \mid \hat{\delta}_{trans} \mid) \\ *prob(\delta_{trans} - \hat{\delta}_{trans}, \alpha_3 \mid \hat{\delta}_{trans} \mid + \alpha_4(\mid \hat{\delta}_{rot1} \mid + \mid \hat{\delta}_{rot2} \mid) \\ *prob(\delta_{rot2} - \hat{\delta}_{rot2}, \alpha_1 \mid \hat{\delta}_{rot2} \mid + \alpha_2 \hat{\delta}_{trans}) \end{aligned}$$

Odometry Motion Model - Sampling



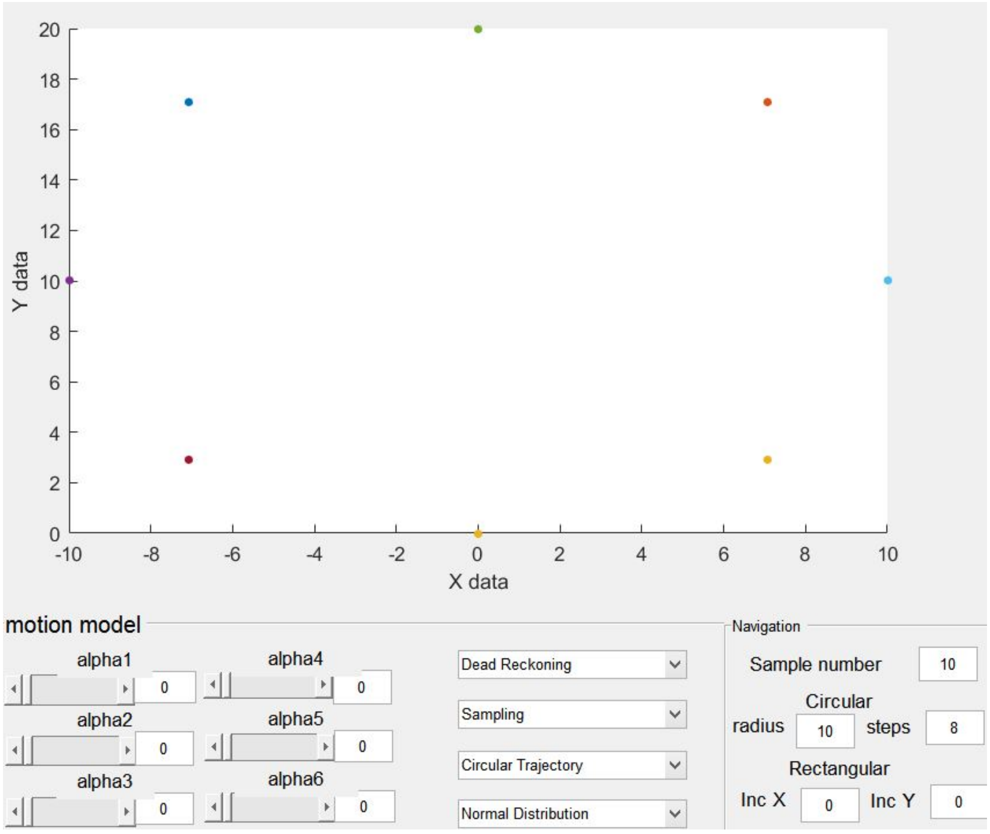
$$\hat{\delta}_{trans} = \delta_{trans} + sample(\alpha_1 \mid \delta_{rot1} \mid + \alpha_2 \mid \delta_{trans} \mid)$$
$$\hat{\delta}_{rot1} = \delta_{rot1} + sample(\alpha_3 \mid \delta_{trans} \mid + \alpha_4(\mid \delta_{rot1} \mid + \mid \delta_{rot2} \mid))$$
$$\hat{\delta}_{rot2} = \delta_{rot2} + sample(\alpha_1 \mid \delta_{rot2} \mid + \alpha_2 \delta_{trans})$$

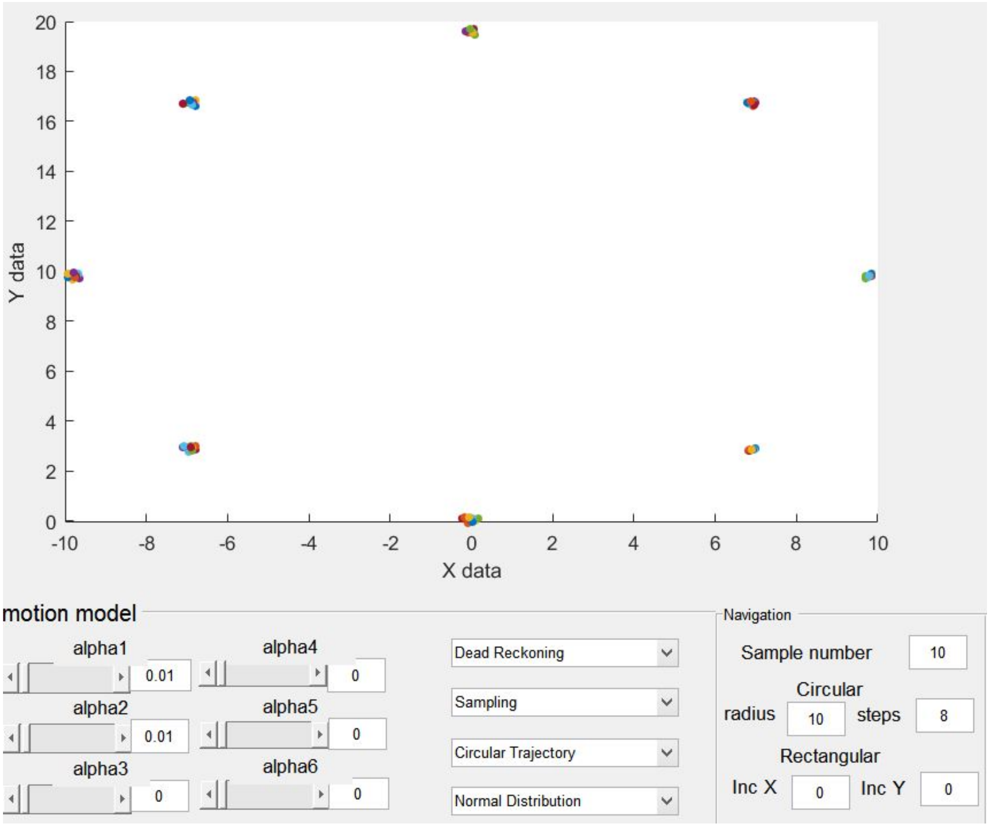
Computing state at time t

$$x^{'} = x + \hat{\delta}_{trans} \cos(\theta + \hat{\delta}_{rot1}$$
$$y^{'} = y + \hat{\delta}_{trans} \sin(\theta + \hat{\delta}_{rot1}$$
$$\theta^{'} = \theta + \hat{\delta}_{rot1} + \hat{\delta}_{rot2}$$

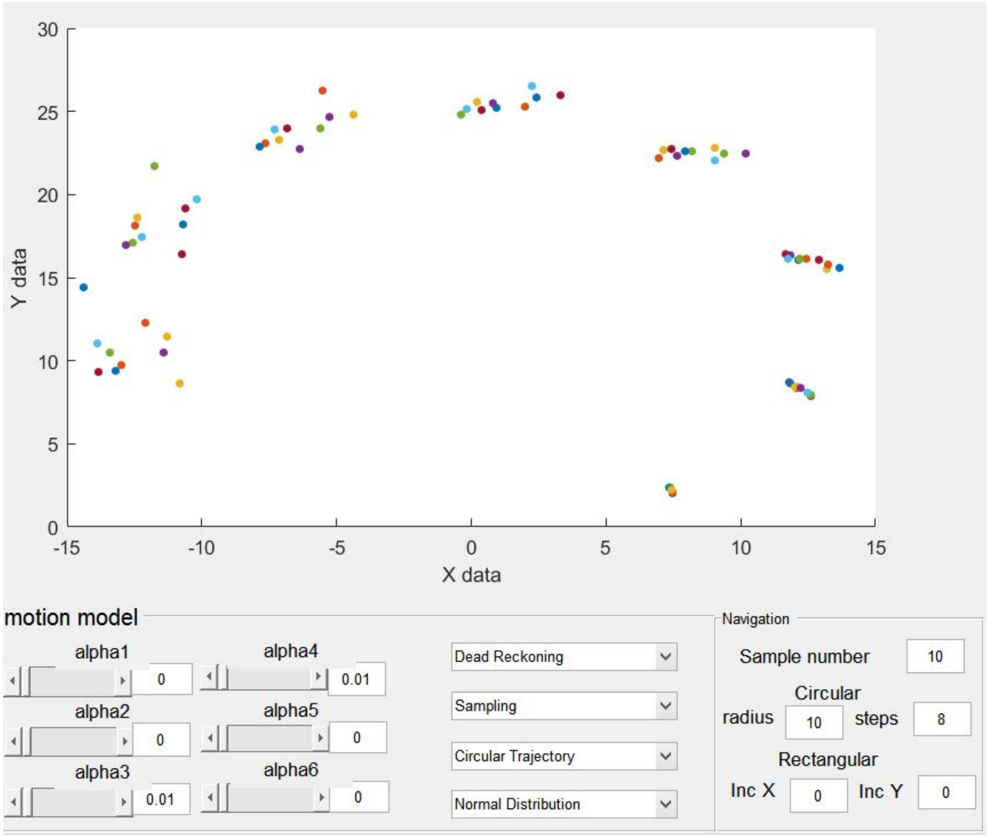
Odometry Sampling Results

With no uncertainty


Y data
X data
motion model
alpha1
alpha2
alpha3
alpha4
alpha5
alpha6
Dead Reckoning
Sampling
Circular Trajectory
Normal Distribution
Navigation
Sample number
Circular
radius
steps
Rectangular
Inc X
Inc Y



Y data
X data
motion model
alpha1
0.01
alpha2
0.01
alpha3
0
alpha4
0
alpha5
0
alpha6
0
Dead Reckoning
Sampling
Circular Trajectory
Normal Distribution
Navigation
Sample number
10
Circular
radius
10
steps
8
Rectangular
Inc X
0
Inc Y
0


30
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X data
motion model
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Normal Distribution
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Sample number
10
Circular
radius
10
steps
8
Rectangular
Inc X
0
Inc Y
0