Data Files

The matlab file has the following data:

Velocity (wheel velocity in m/sec (at the encoder position))
Steering (steering angle in radians with respect to the Forward direction)
Time_VS (time stamp in seconds for velocity and Steering)

GPSLat (Latitude in meter with respect to the initial point)
GPSLon (Longitude in meter with respect to the initial point)
TimeGPS (Time Stamp in seconds for GPS)

Laser (360 observations of range in meters 0.5 degrees apart)
TimeLaser (Time stamp in seconds for laser information)

For Implementation purposes we have prepared the following vectors:

Time (Time stamps for the three sensor from initial time to final time)
Sensor (1 : GPS, 2 : Vel and Steering , 3: Laser)
Index (Index position where the data for this sensor is located)

The user now has to scan the Time vector to get the first data. Time (1) has the time stamp of the data which has taken with Sensor(1), the data is in location Index(1) of the particular sensor.

For example if Time(35)=30.6, Sensor(35) = 2 and Index(35)=6
Implies that
At time 30.6 seconds Velocity and Steering was available and this data is at Velocity(6) and Steering(6)

If Time(35)=30.6, Sensor(35) = 3 and Index(35)=2
At time 30.6 seconds Laser was available and this data is at Laser(2, 1:361);

If Time(35)=30.6, Sensor(35) = 1 and Index(35)=2
At time 30.6 seconds Laser was available and this data is at GPSLat(2) and GPSLon(2)

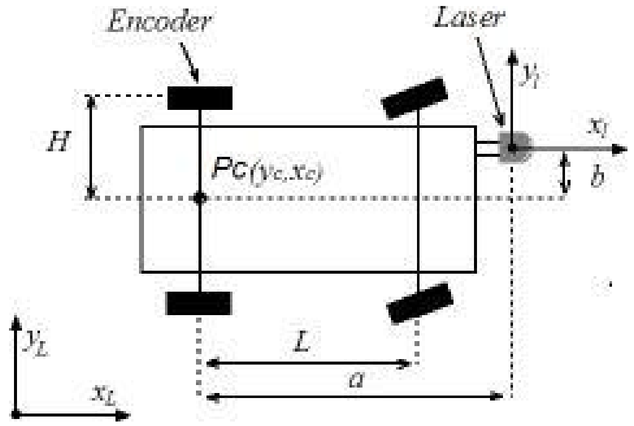
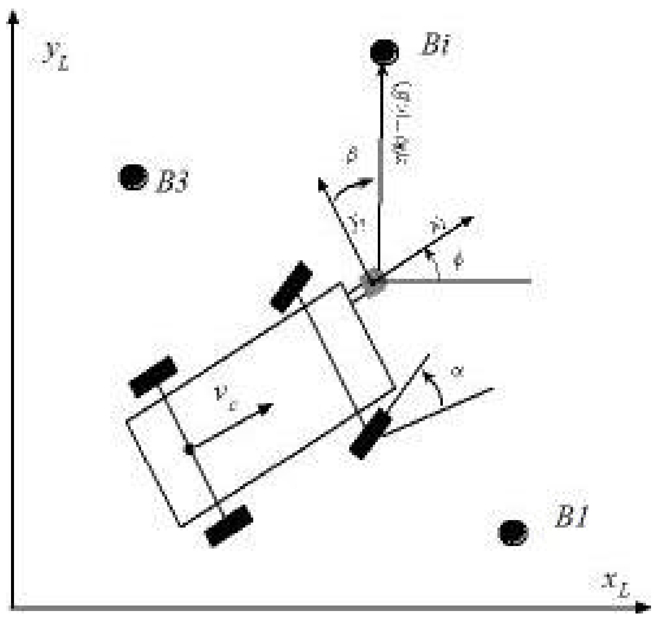


Figure 1 . Vehicle kinematics



Vehicle and Laser sensor

Vehicle Model:

$$\begin{bmatrix} \dot{x}_c \\ \dot{y}_c \\ \dot{f} \end{bmatrix} = \begin{bmatrix} v_c \cos(f) \\ v_c \sin(f) \\ v_c \tan(a) \end{bmatrix}$$

Now, if we translate our model to the gps and laser point, let us call this point (x_v, y_v).

$$\begin{bmatrix} x_v \\ y_v \end{bmatrix} = \begin{bmatrix} x_c + a\cos f - b\sin f \\ y_c + a\sin f + b\cos f \end{bmatrix}$$

The velocity v_c is measured with an encoder locate in the back left wheel. This velocity is translated to the center of the axle with the following equation:

$$v_c = \frac{v_e}{\left(1 - \tan(a)\frac{H}{L}\right)}$$

For our vehicle:

$$L = 2.83, \quad H = 0.76, \quad b = 0.5, \quad a = 3.78$$

Finally the discrete model in global coordinates can be approximated with the following set of equations:

$$\begin{bmatrix} x(k+1) \\ y(k+1) \\ f(k+1) \end{bmatrix} = f(x,u) = \begin{bmatrix} x(k) + \Delta T(v_c \cos(f) - \frac{v_c}{L}\tan(f)(a\sin(f) + b\cos(f))) \\ y(k) + \Delta T(v_c \sin(f) + \frac{v_c}{L}\tan(f)(a\cos(f) + -b\sin(f))) \\ f(k) + \Delta T\frac{v_c}{L}\tan(a) \end{bmatrix}$$

Jacobian:

$$\frac{\partial f}{\partial X} = \begin{bmatrix} 1 & 0 & -\Delta T(v_c \sin(f) + \frac{v_c}{L}\tan a\,(a\cos(f) - b\sin(f))) \\ 0 & 1 & \Delta T(v_c \cos(f) - \frac{v_c}{L}\tan a\,(a\sin(f) + b\cos(f))) \\ 0 & 0 & 1 \end{bmatrix}$$

Observation model for range and bearing sensor:

$$\begin{bmatrix} z_r \\ z_b \end{bmatrix} = h(x) = \begin{bmatrix} \sqrt{(x_L - x_v)^2 + (y_L - y_v)^2} \\ \text{atan}\left(\frac{(y_L - y_v)}{(x_L - x_v)}\right) - f + \frac{p}{2} \end{bmatrix}$$

Jacobians:

$$\frac{\partial h}{\partial X} = \begin{bmatrix} \frac{\partial h_r}{\partial x} \\ \frac{\partial h_b}{\partial x} \end{bmatrix} = \begin{bmatrix} \frac{\partial z_r}{\partial(x_v, y_v, f_v)} \\ \frac{\partial z_b}{\partial(x_v, y_v, f_v)} \end{bmatrix}$$

with

$$\frac{\partial h_r}{\partial X} = \frac{1}{\Delta}[-\Delta x, -\Delta y, 0]$$

$$\frac{\partial h_b}{\partial X} = \left[\frac{\Delta y}{\Delta^2}, -\frac{\Delta x}{\Delta^2}, -1\right]$$

$$\Delta x = (x_L - x_v) \qquad \Delta y = (y_L - y_v)$$

$$\Delta = \sqrt{\Delta x^2 + \Delta y^2}$$

Where

$\{x_v, y_v, f_v\}$ are the vehicles state variables.

$\{x_L, y_L\}$ is the landmark position.

For the Slam case, where the state vector is the vehicle posse and beacons position:

$$\frac{\partial h}{\partial X} = \begin{bmatrix} \frac{\partial h_r}{\partial x} \\ \frac{\partial h_b}{\partial x} \end{bmatrix} = \begin{bmatrix} \frac{\partial z_r}{\partial (x_v, y_v, f_v, \{x_L, y_L\})} \\ \frac{\partial z_b}{\partial (x_v, y_v, f_v, \{x_L, y_L\})} \end{bmatrix}$$

with

$$\frac{\partial h_r}{\partial X} = \frac{1}{\Delta}\left[-\Delta x, -\Delta y, 0, 0, 0, ...\Delta x, \Delta y, 0, 0....0\right]$$

$$\frac{\partial h_b}{\partial X} = \left[\frac{\Delta y}{\Delta^2}, -\frac{\Delta x}{\Delta^2}, -1, 0, 0, ..., -\frac{\Delta y}{\Delta^2}, \frac{\Delta x}{\Delta^2}, 0, 0...0\right]$$

$$\Delta x = \left(x_L - x_v\right) \qquad \Delta y = \left(y_L - y_v\right)$$

$$\Delta = \sqrt{\Delta x^2 + \Delta y^2}$$