1. Appendix A

To estimate the travelling area of each detected nearby vehicle, the position relations between the real position of the target vehicle and its nearby vehicles are firstly provided. Given an assumed real position P_T^i=[$X(T_i)$, $Y(T_i)$] of the target vehicle T_i. Then, the real position P_N^{ij}=[$X(N_i^j)$, $Y(N_i^j)$] of the nearby vehicle N_i^j can be expressed as:

$$\begin{aligned} X(N_i^j) &= X(T_i) + PD(T_i, N_i^j)_X \\ &= X(T_i) + d(T_i, N_i^j)cos(a(T_i, N_i^j)), \end{aligned} \tag{1.1}$$

$$\begin{aligned} Y(N_i^j) &= Y(T_i) + PD(T_i, N_i^j)_Y \\ &= Y(T_i) + d(T_i, N_i^j)sin(a(T_i, N_i^j)), \end{aligned} \tag{1.2}$$

where [$PD(T_i, N_i^j)_X$, $PD(T_i, N_i^j)_Y$] is the *real position difference (PD)* between the target vehicle T_i and nearby vehicle N_i^j

The real position difference between the target vehicle T_i and nearby vehicle N_i^j can be expressed as:

$$\begin{aligned} PD(T_i, N_i^j)_X &= [\hat{d}(T_i, N_i^j) - \varepsilon_d]cos(\hat{a}(T_i, N_i^j) - \varepsilon_a), \\ PD(T_i, N_i^j)_Y &= [\hat{d}(T_i, N_i^j) - \varepsilon_d]sin(\hat{a}(T_i, N_i^j) - \varepsilon_a), \end{aligned} \tag{1.3}$$

where ε_d and ε_a are the measurement errors of relative distance and bearing angle, and ε_d and ε_a follow Gaussian distributions with the standard deviations ρ and ω respectively.

Eq. 1.3 can be approximately estimated using the 1^{st} Tayler expansion as follows:

$$\begin{aligned} PD(T_i, N_i^j)_X &\approx \hat{d}(T_i, N_i^j)cos(\hat{a}(T_i, N_i^j)) + \varepsilon_x^{PD} \\ &= \hat{PD}(T_i, N_i^j)_X + \varepsilon_x^{PD}, \\ PD(T_i, N_i^j)_Y &\approx \hat{d}(T_i, N_i^j)sin(\hat{a}(T_i, N_i^j)) + \varepsilon_y^{PD} \\ &= \hat{PD}(T_i, N_i^j)_Y + \varepsilon_y^{PD}, \end{aligned} \tag{1.4}$$

where ε_x^{PD} and ε_y^{PD} are the estimated errors of the measured position difference in order to offset the measurement errors of relative positions. ε_x^{PD} and ε_y^{PD} are determined as follows:

$$\begin{aligned} \varepsilon_x^{PD} &= -\varepsilon_d cos(\hat{a}(T_i, N_i^j))) + \varepsilon_a \hat{d}(T_i, N_i^j)sin(\hat{a}(T_i, N_i^j)), \\ \varepsilon_y^{PD} &= -\varepsilon_d sin(\hat{a}(T_i, N_i^j))) - \varepsilon_a \hat{d}(T_i, N_i^j)cos(\hat{a}(T_i, N_i^j)), \end{aligned} \tag{1.5}$$

According to Trigonometric Equations, Eq. 1.5 can be expressed as:

$$\begin{aligned} \varepsilon_x^{PD} &= Rcos(\hat{a}(T_i, N_i^j)) + \alpha), \\ \varepsilon_y^{PD} &= -Rsin(\hat{a}(T_i, N_i^j)) + \alpha), \end{aligned} \tag{1.6}$$

where

$$\begin{aligned} R &= \sqrt{(-\varepsilon_d)^2 + (\varepsilon_a \hat{d}(T_i, N_i^j))^2}, \\ \alpha &= tan^{-1}(\frac{\varepsilon_a \hat{d}(T_i, N_i^j)}{\varepsilon_d}). \end{aligned} \tag{1.7}$$

2. Appendix B

To determine the probability density function (PDF) of displacement difference in terms of the real position of the target vehicle, the displacement of the target vehicle in terms of the real position is determined as:

$$\text{Vec}(P_T^i \rightarrow \hat{P}_T^i) = \hat{P}_T^i - P_T^i, \tag{2.1}$$

where $\hat{P}_T^i$ is the GPS position of the target vehicle T_i and P_T^i is the real position of the target vehicle.

Similarly the displacement of the nearby vehicle N_i^j in terms of real position is determined as follows:

$$\text{Vec}(P_N^{ij} \rightarrow \hat{P}_N^{ij}) = \hat{P}_N^{ij} - P_N^{ij}, \tag{2.2}$$

where P_N^{ij} and $\hat{P}_N^{ij}$ are the real position and GPS position of the nearby vehicle N_i^j.

As the accuracy of GPS measurements depends on the quality of the pseudorange measurement between the satellites and GPS receivers with the consideration of common error sources (e.g., atmospheric delay, satellite clock and ephemeris errors, etc.), and uncommon eror sources (e.g., the noise of GPS receivers). When vehicles are driving in a vicinity, these vehicles are assumed to have the GNSS data coming from the same constellation of satellites. However, as non-common errors vary from vehicle to vehicle, the bias in GPS positioning caused by uncommon errors is usually modelled following an vehicle-dependent zero-mean Gaussian distribution.

Therefore, given the target vehicle T_i, the measured GPS position of the target vehicle T_i can be formulated as:

$$\hat{P}_T^i = P_T^i + B_T^i + NB_T^i, \tag{2.3}$$

where P_T^i represents the real position of T_i, B_T^i represents the position bias caused by common errors, and NB_T^i denotes the position bias caused by non-common errors. NB_T^i is modelled following a Gaussian distribution $N(0, \sigma^2_{NB_T^i})$, where $\sigma_{NB_T^i}$ is the standard deviation of NB_T^i.

Similarly, the measured GPS position of its j^{th} nearby vehicle N_i^j can be written as:

$$\hat{P}_N^{ij} = P_N^{ij} + B_N^{ij} + NB_N^{ij}, \tag{2.4}$$

where P_N^{ij} represents the real position of N_i^j, B_N^{ij} represents the position bias caused by common errors, NB_N^{ij} represents the position bias caused by non-common errors. NB_N^{ij} follows a Gaussian distribution $N(0, \sigma^2_{NB_N^{ij}})$, where $\sigma_{NB_N^{ij}}$ is the corresponding standard deviation of NB_N^{ij}.

As the bias caused by common error sources $B_T^i \approx B_N^{ij}$ when the target vehicle T_i and nearby vehicle N_i^j in a vicinity. Therefore, by subtracting Eq. 2.4 from Eq. 2.3, we have:

$$\hat{P}_T^i - \hat{P}_N^{ij} \approx P_T^i - P_N^{ij} + NB_T^i - NB_N^{ij}. \tag{2.5}$$

where the difference of the GPS position of the target vehicle and nearby vehicle can be determined as the real position difference and the difference of the independent position bias caused by the uncommon errors.

Therefore, the displacement difference DD in terms of the real position of the target vehicle can be computed from Eq. 2.1, Eq. 2.2 and Eq. 2.5 as follows:

$$
\begin{aligned}
DD(T_i, N_i^j, P_T^i) &= \mathrm{Vec}(P_T^i \to \hat{P}_T^i) - \mathrm{Vec}(P_N^{ij} \to \hat{P}_N^{ij}) \\
&= (\hat{P}_T^i - P_T^i) - (\hat{P}_N^{ij} - P_N^{ij}) \\
&= (\hat{P}_T^i - \hat{P}_N^{ij}) + (P_N^{ij} - P_T^i) \\
&\approx (NB_T^i - NB_N^{ij}).
\end{aligned} \tag{2.6}
$$

Since NB_T^i and NB_N^{ij} are assumed as independent Gaussian distributions $N(0, \sigma^2_{NB_T^i})$ and $N(0, \sigma^2_{NB_N^{ij}})$, therefore $(NB_T^i - NB_N^{ij})$ follows a Gaussian distribution $N(0, \sigma^2_{NB_T^i} + \sigma^2_{NB_N^{ij}})$, where $\sigma_{NB_T^i}$ and $\sigma_{NB_N^{ij}}$ are the standard deviations of NB_T^i and NB_N^{ij} respectively.