**MPC Path Planner**

At current time, solve following optimization problem. $N$ is horizon length, $M$ is the number of detected obstacles. The pair $z_k := (x_k, y_k)$ is a position of vehicle at time $k$.$\tau_k^i$ is the position of $i^{th}$ obstacle (vehicles) at time $k$. $T$ is a goal position, $f_z$ and $f_\tau^i$ are dynamics for ego vehicle and $i^{th}$ obstacle. There are two kinds of obstacles. Static obstacle and dynamics obstacle (other vehicle).

$$\begin{aligned} \min_{u \in U} & \sum_{k=1}^{N} D_k^2(z_k) + \sum_{i=1}^{M} \sum_{k=1}^{N} P_k^i(z_k, \tau_k^i) \\ s.t. \quad & z_{k+1} = f_z(z_k, u_k), \\ & \tau_{k+1} = f_\tau(\tau_k, u_k), \\ & \textit{Comfort constraint}, \end{aligned} \tag{1}$$

where

$$P_k^i(z_k, \tau_k^i) := w \frac{\exp(-\alpha(\|z_k - \tau_k^i\|^2 - s^2))}{1 + \exp(-\alpha(\|z_k - \tau_k^i\|^2 - s^2))} \tag{2}$$

$$D_k(z_k) = \|z_k - T\| \tag{3}$$

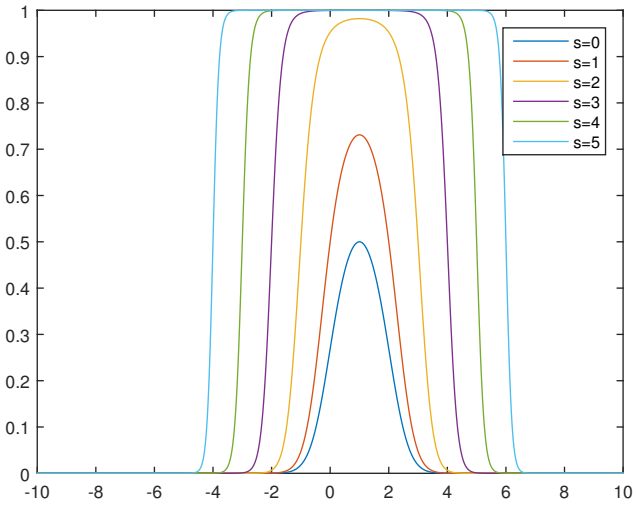
$P_k^i$ applies large penalty to the position of the $i^{th}$ obstacle that is located at $\tau^i$ at time $k$.

Fig.1 shows the effect of two tuning parameters $s$ and $\alpha$. horizontal axis is $x$, vertical axis is $z$ for both subfigures. As shown in Fig.1(a), the parameter $s$ determines the range of penalty effect and the parameter $\alpha$ determines growing rate of the penalty. In the future, both parameters could be a function of speed of vehicle.

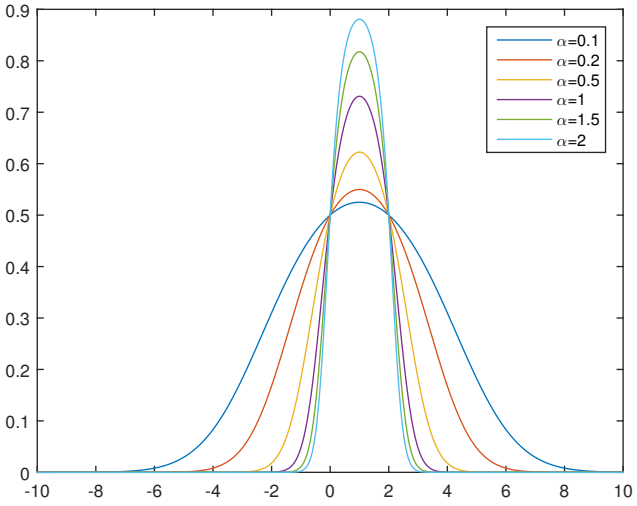
Note that Eq.(2) realizes cut-in and yield(let others to cut in) plan.

## Lane Change

Choosing goal position $T$ is a design parameter. If $T$ is located in the center line of any lane, vehicle path converge to the corresponding lane.




(a) Parametrized by $s$




(b) Parametrized by $\alpha$

Figure 1: Penalty term parameterized by $s$ and $\alpha$

## Goal Position

Goal should be set based on traffic information such as high way exit location, road merge and so on.