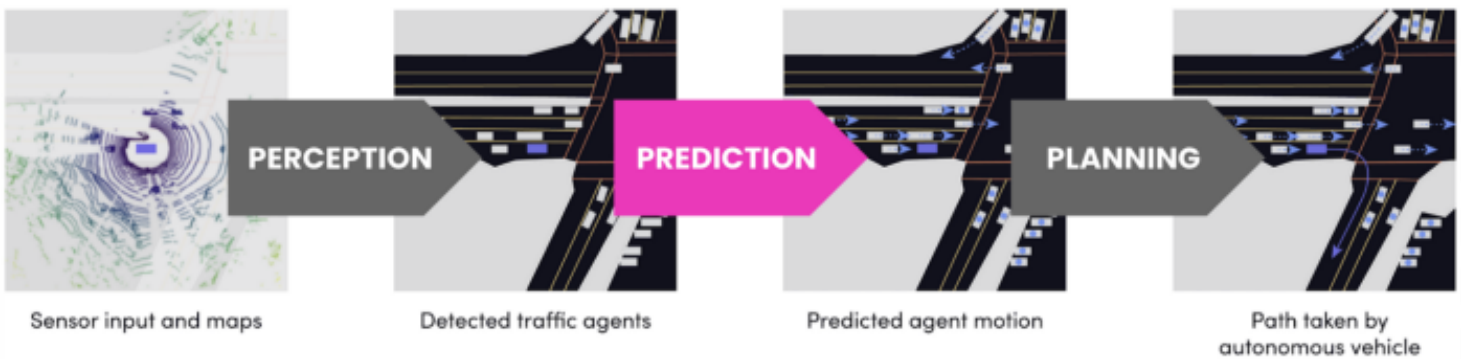
Interpretable Long Term Waypoint-Based Trajectory Prediction Model

Amina Ghoul, Itheri Yahiaoui and Fawzi Nashashibi

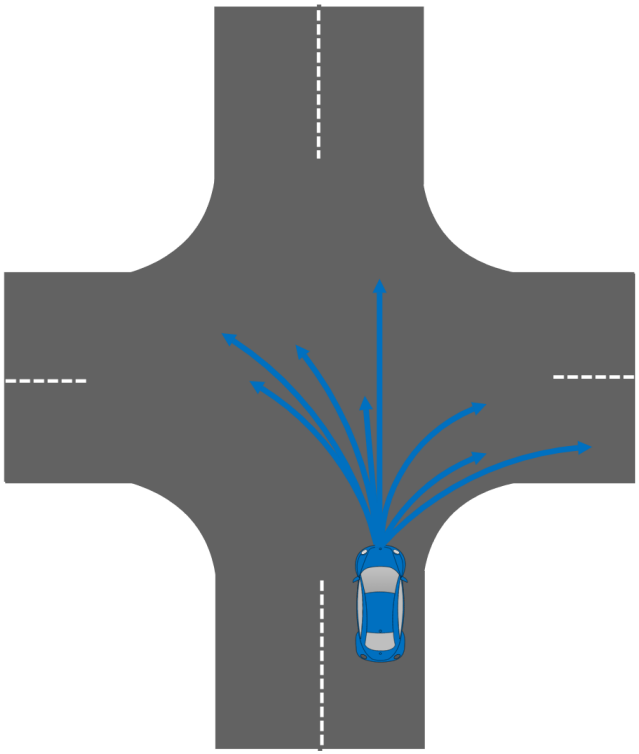
What is motion prediction ?

Predicting agent's future behavior in dynamic, multi agent system.



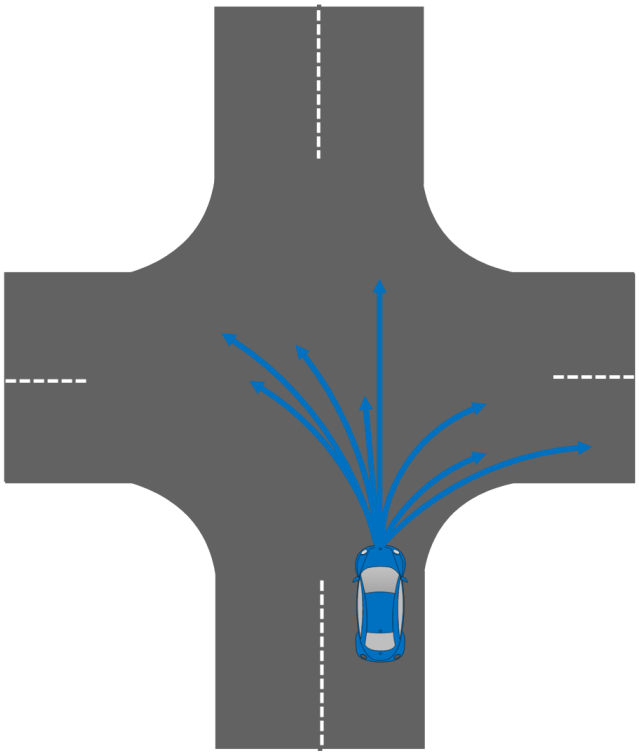
Autonomous vehicle pipeline

Why is motion prediction challenging ?

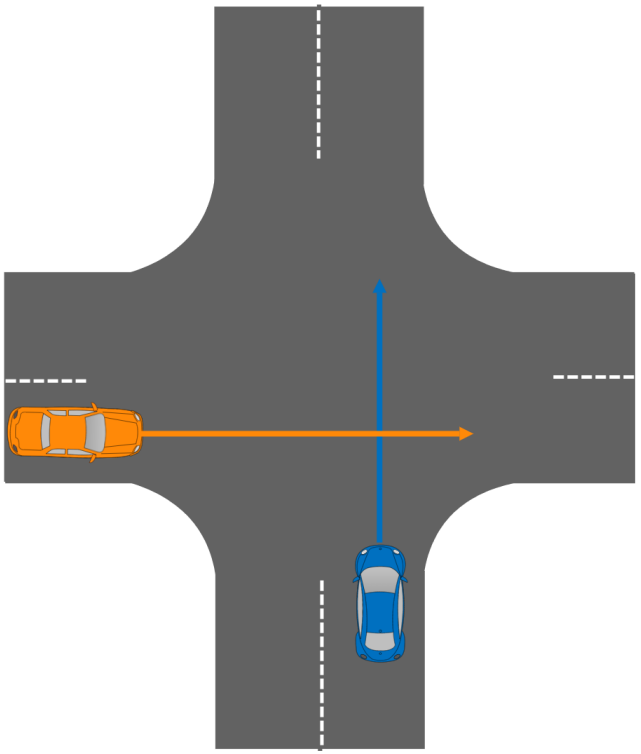


Future is uncertain.

Why is motion prediction challenging ?



Future is uncertain.



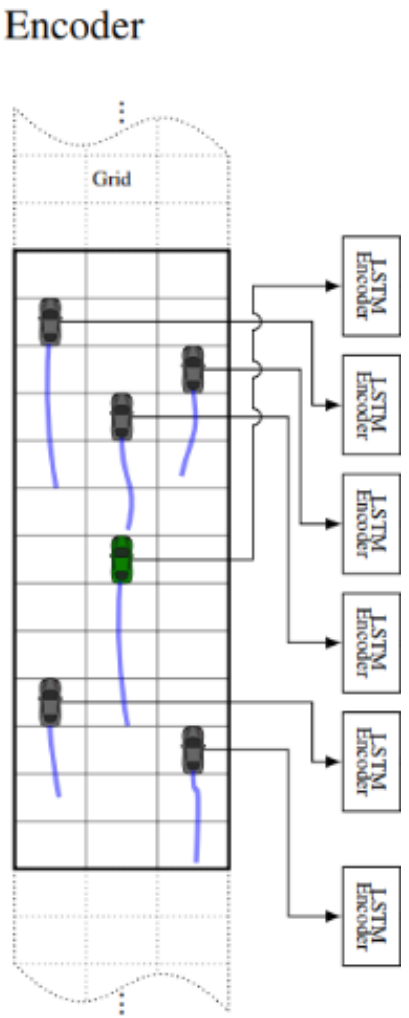
Interaction between agents.

Related Work

Input Representation

Input cues :

- The agents' past states (coordinates, velocity, heading...)



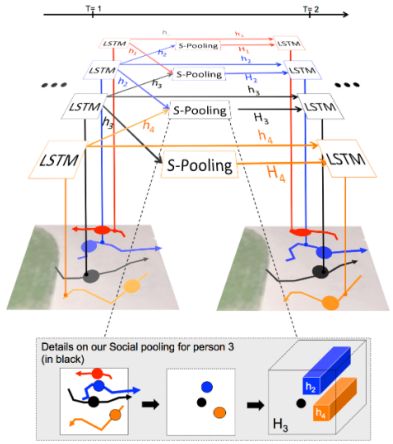
[1] MHA-LSTM : Attention Based Vehicle Trajectory Prediction [Messaoud et. al]

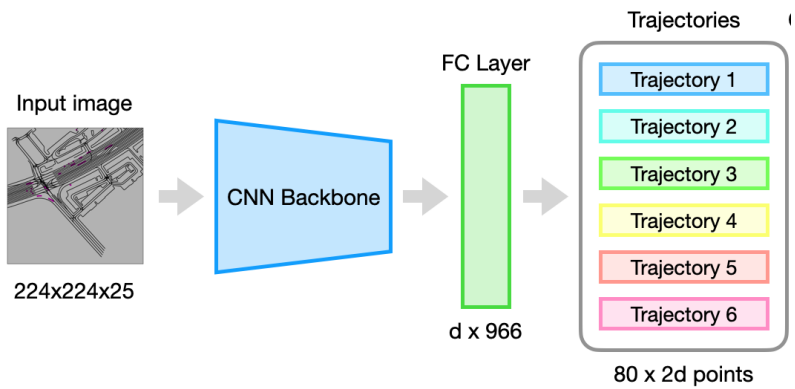
Related Work

Input Representation

Input cues :

- The target agent's past states.
- Interaction with its environment.
  - Other agents.
  - The static scene.



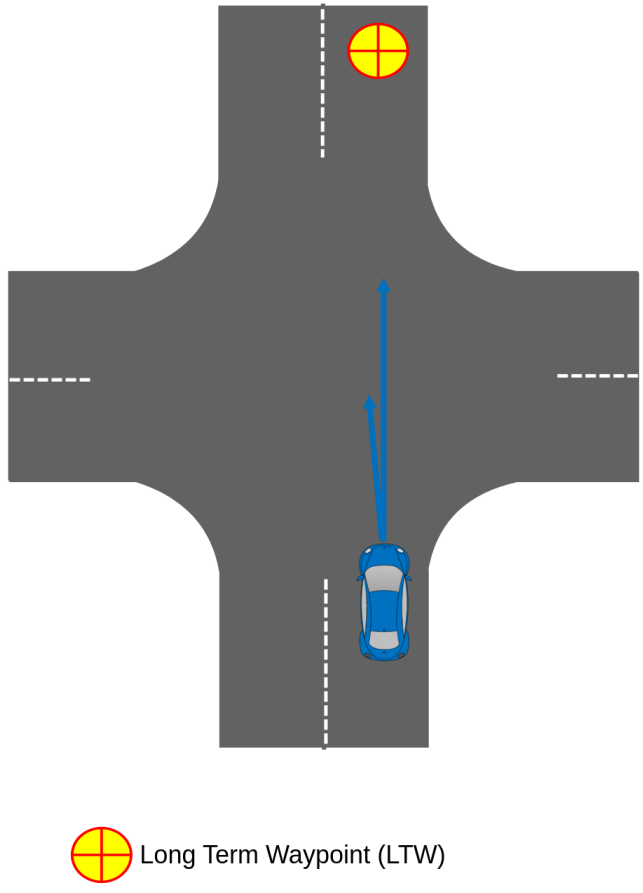


[2] MultiPath++ [Varadarajan et.al], [3] MotionCNN [Konev et.al]

Final destination

Input cues :

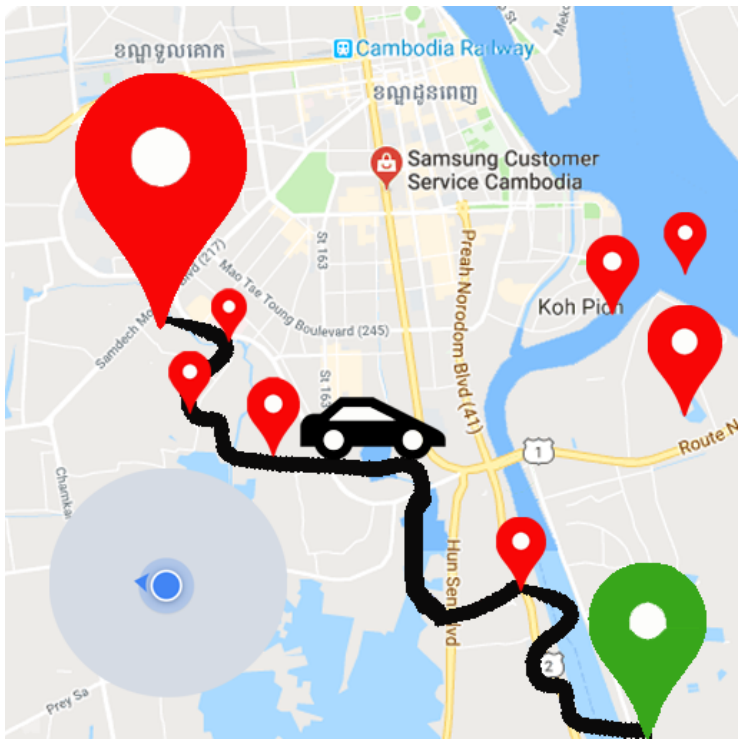
- The target agent's past states.
- Interaction with its environment.
- Its Long Term Waypoint (LTW) : An agent future trajectory is most influenced by its final destination.



Final destination

Input cues :

- The target agent's past states.
- Interaction with its environment.
- Its Long Term Waypoint (LTW) : An agent future trajectory is most influenced by its final destination.
- In practice : GPS provides waypoints to reach the final destination.



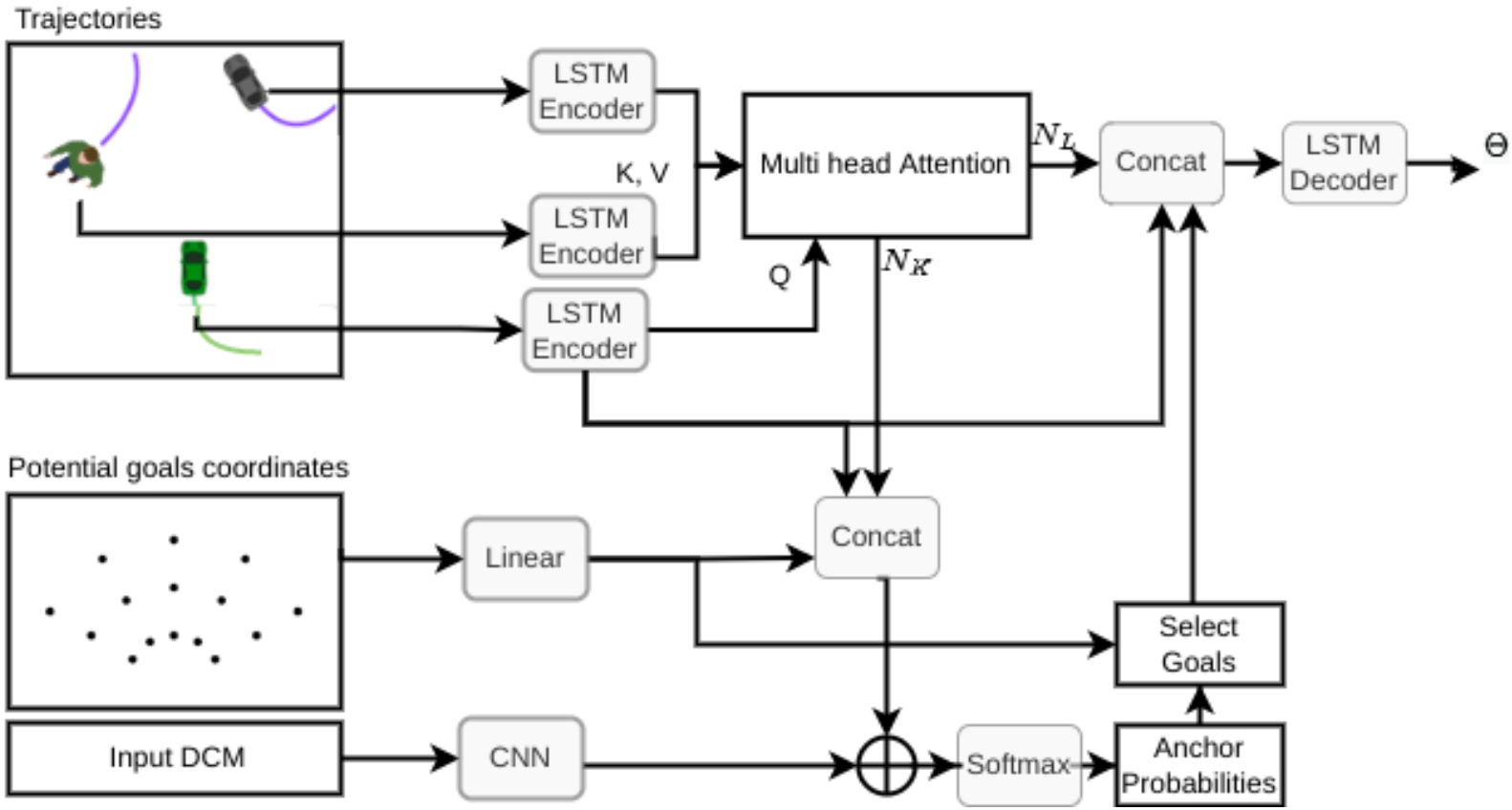
WayDCM

- Follow-up to our previous work : TrajDCM
- Interpretable.
- Lightweight.
- Supervised training.
- Goal based.
- A new type of input : Long Term Waypoints (LTW).

Key insight: The long term waypoint capture most uncertainty of a trajectory.

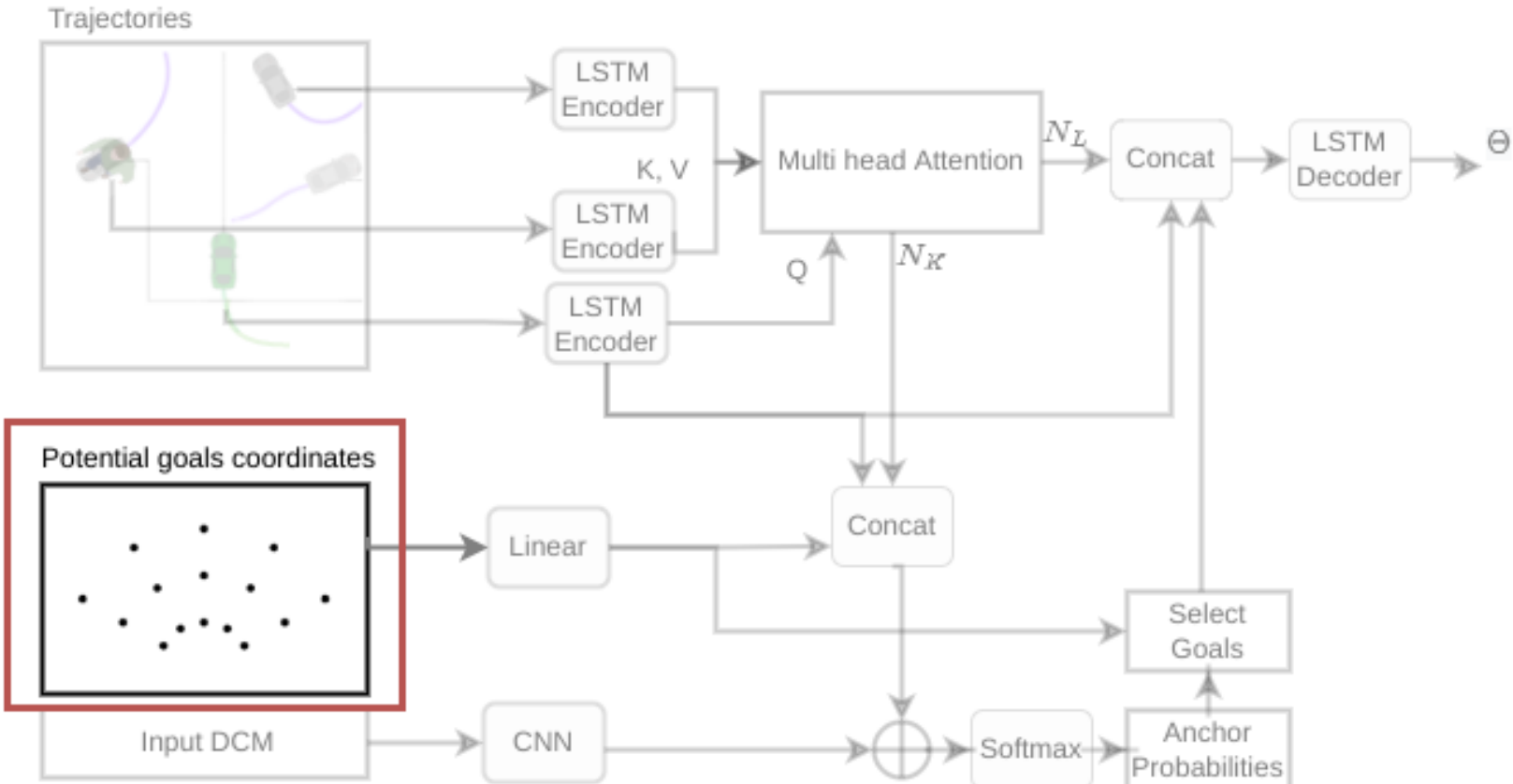
WayDCM

General Architecture



WayDCM

1. Extract potential goals from a dynamic radial grid.



WayDCM

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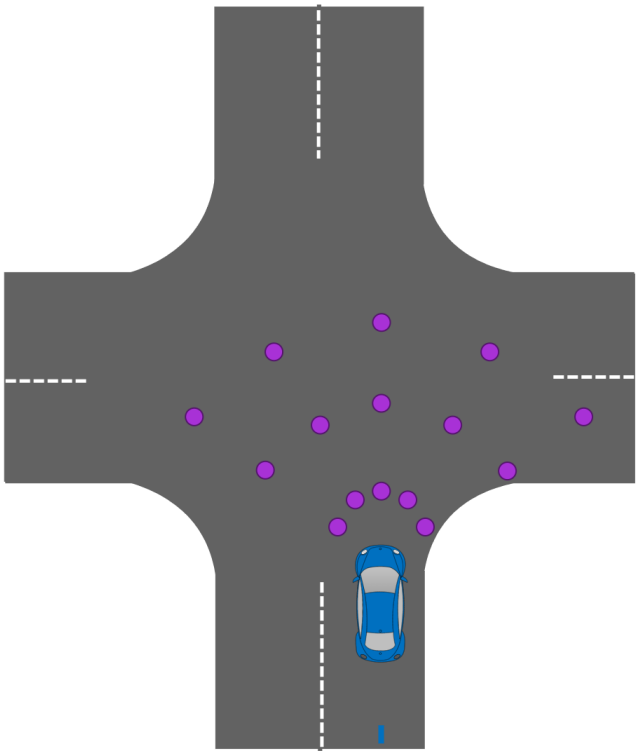
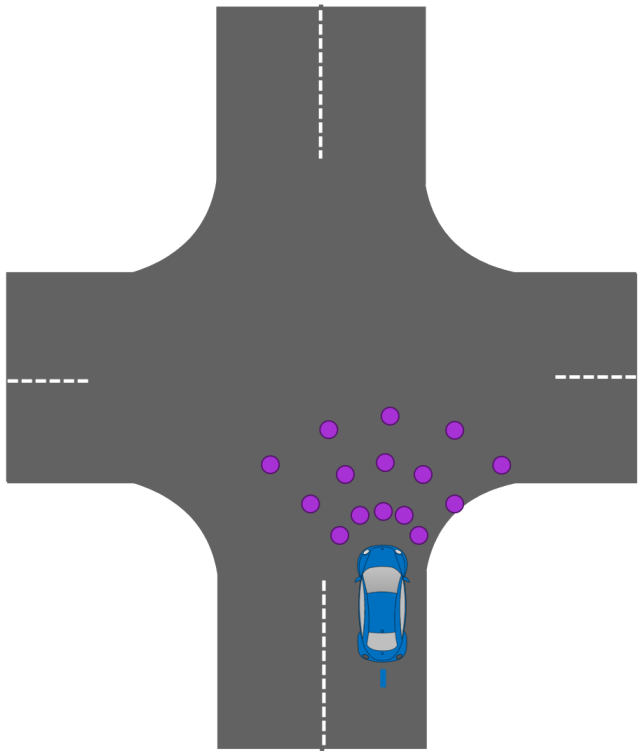
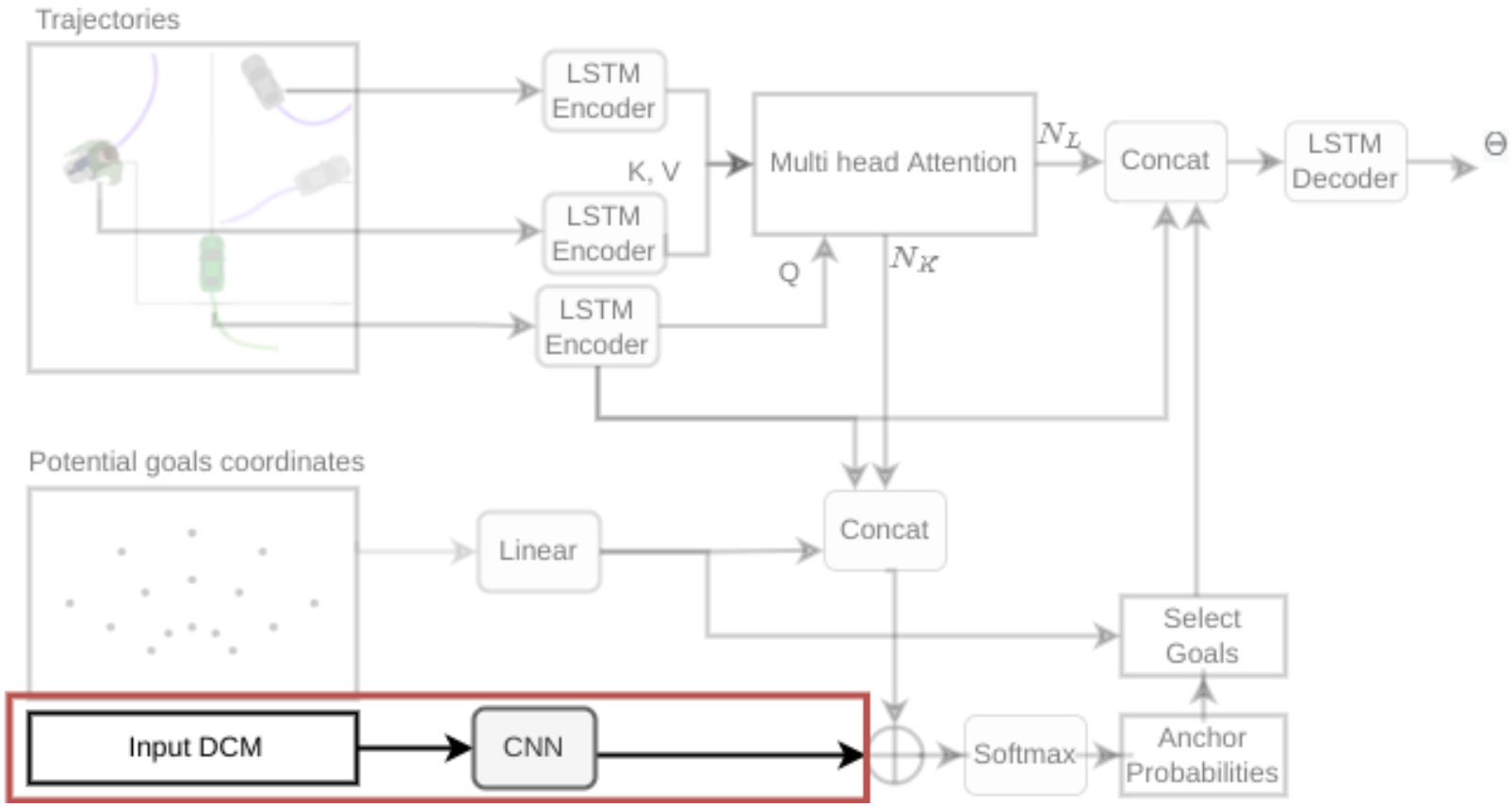


Higher speed.



Lower speed.

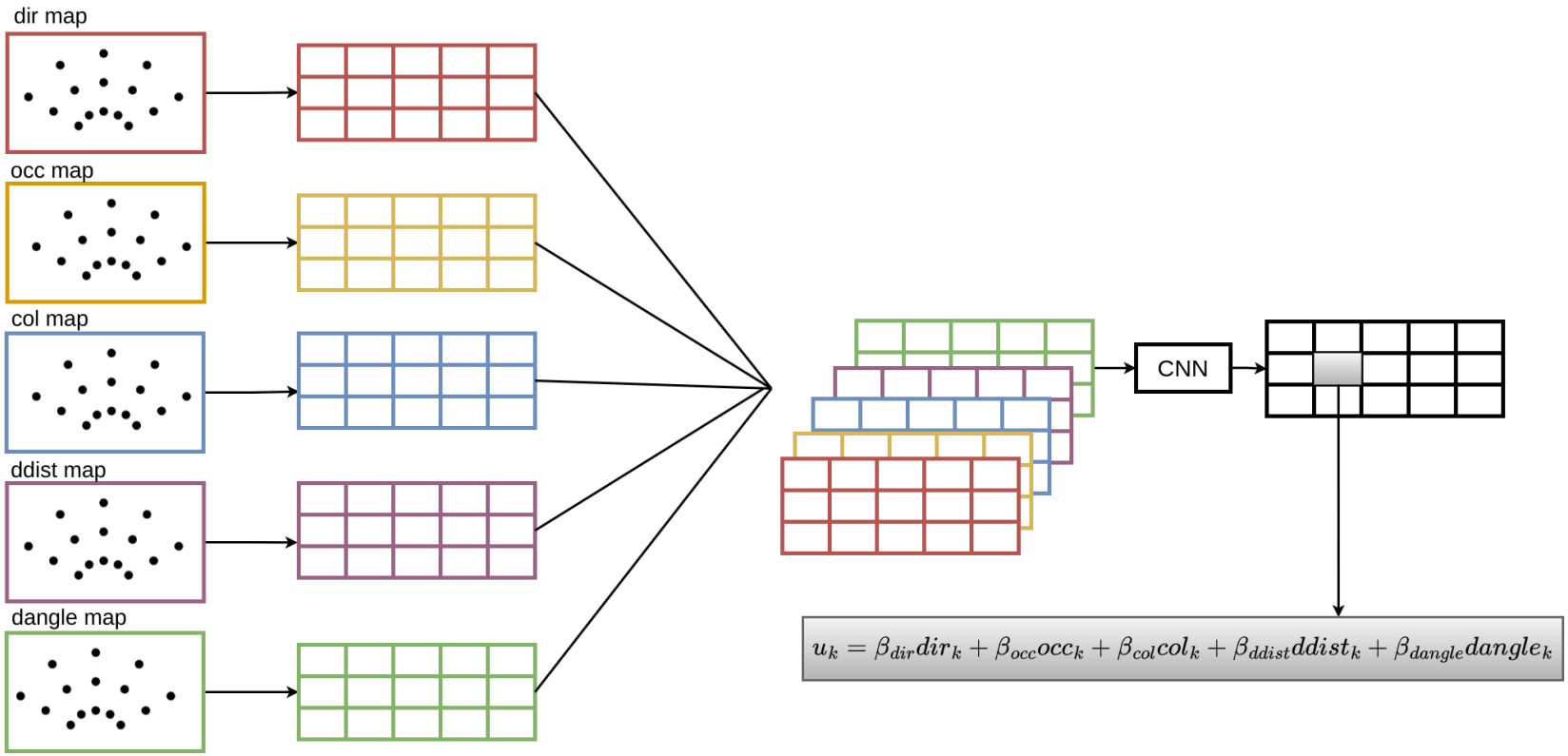
1) Discrete Choice Model (DCM) prediction :



WayDCM

2. Target Prediction

1) DCM prediction :

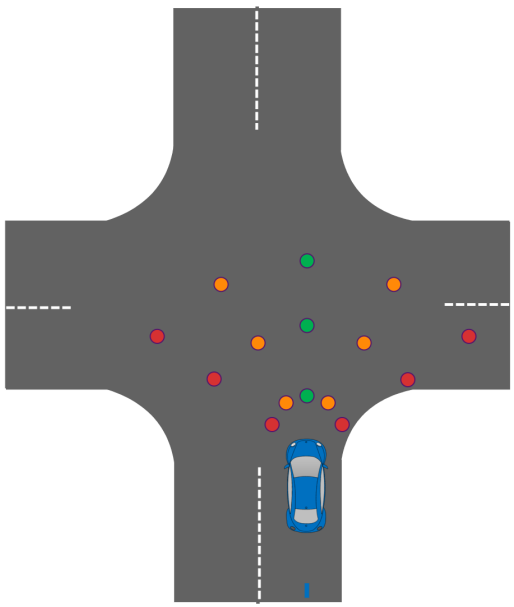


WayDCM

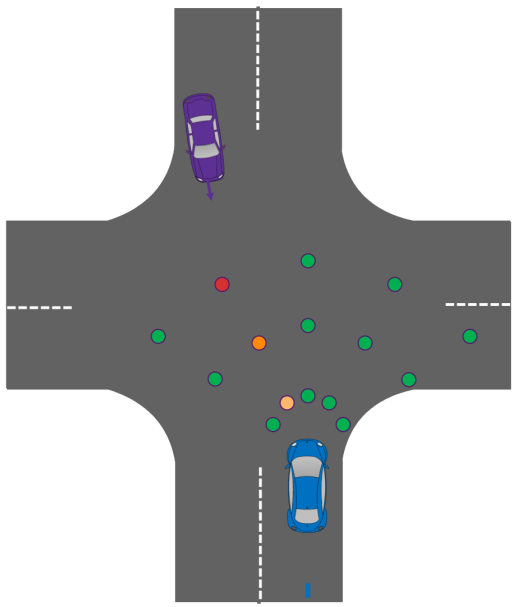
2. Target Prediction

1) DCM prediction :

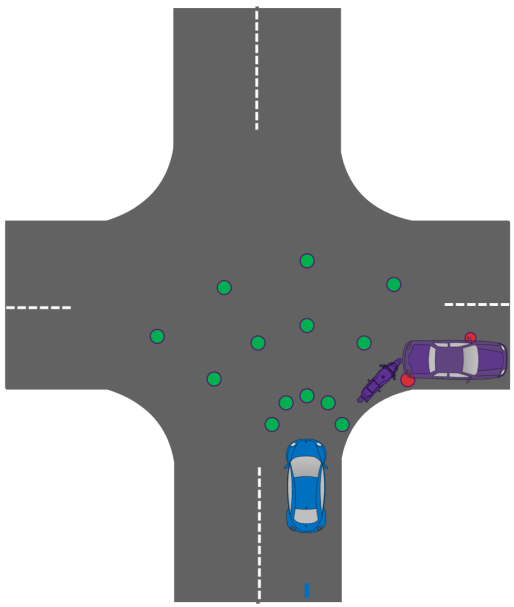
a) Behavioral functions



Keep Direction (dir).



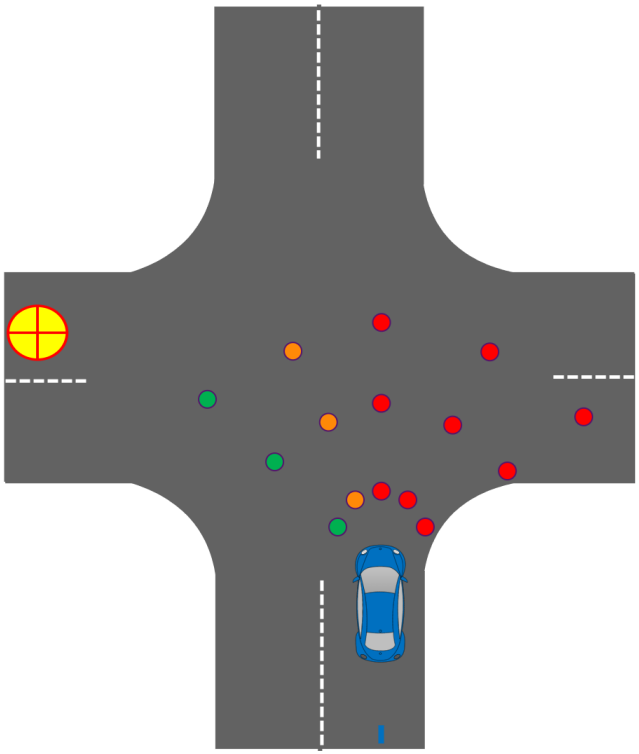
Collision Avoidance (col).



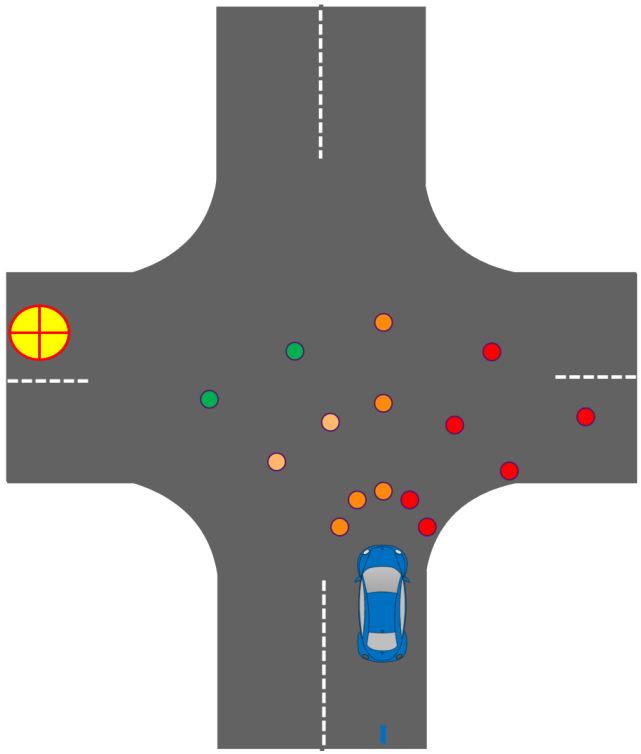
Occupancy/ Overtaking (occ).

1) DCM prediction :

b) Introduction of the LTW

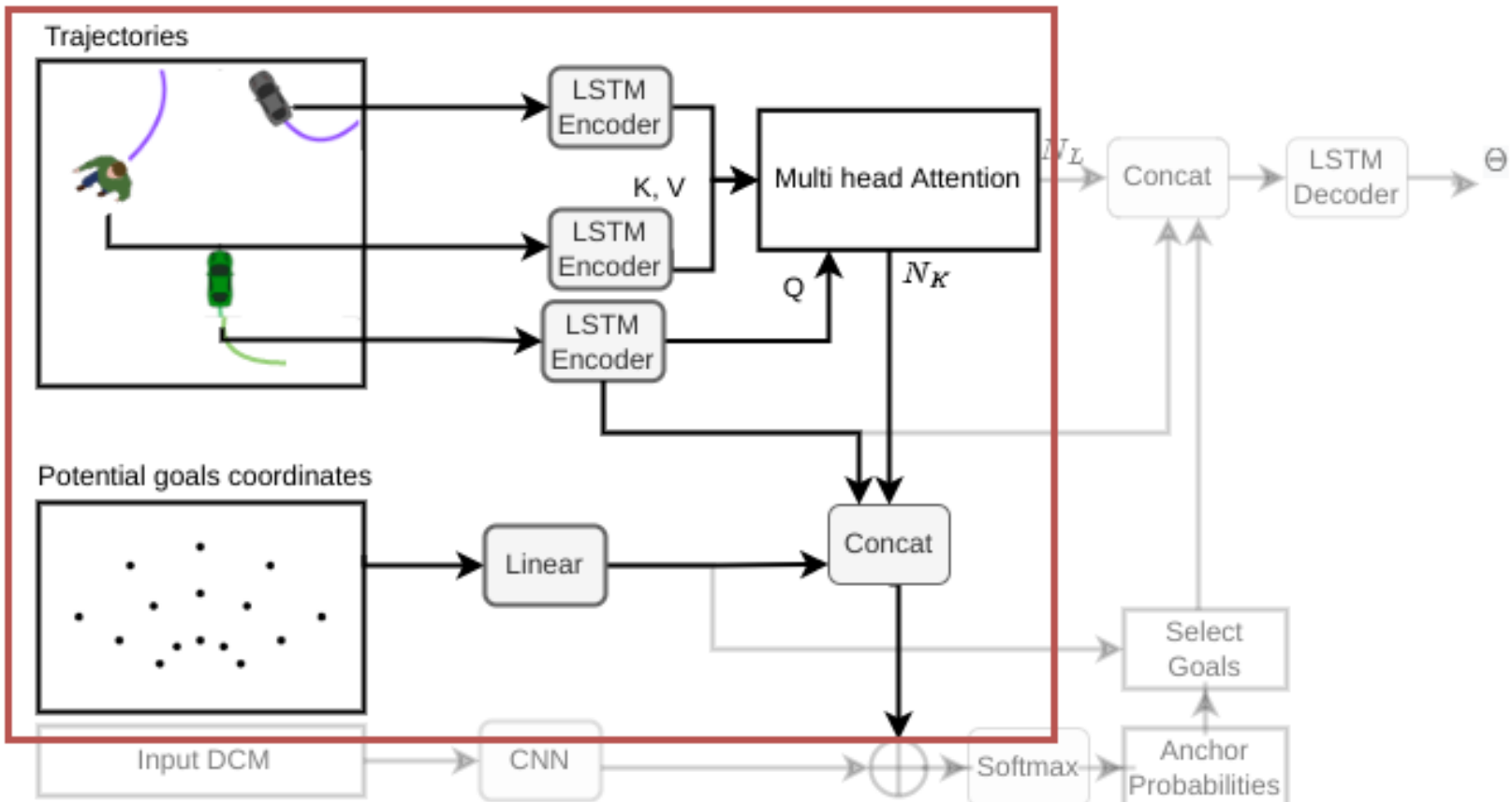


Minimizing the angle (dangle).



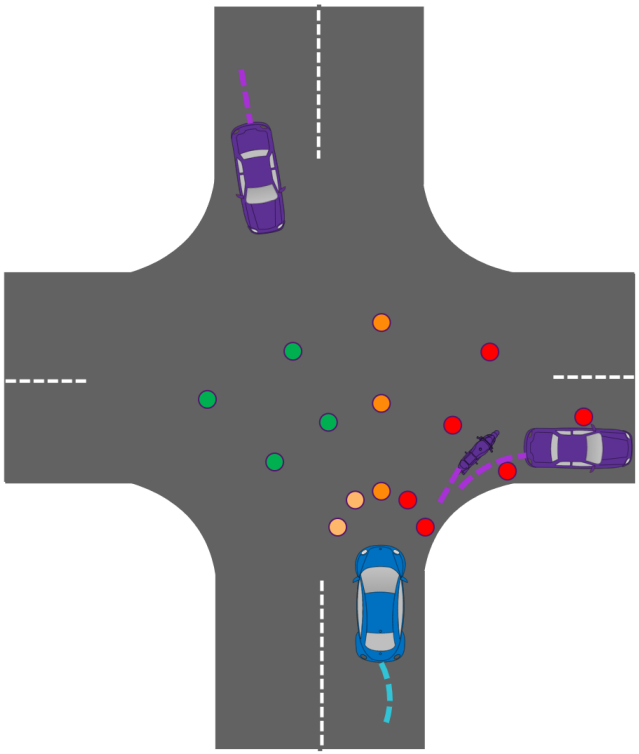
Minimizing the distance (ddist).

2) Neural Network Prediction :



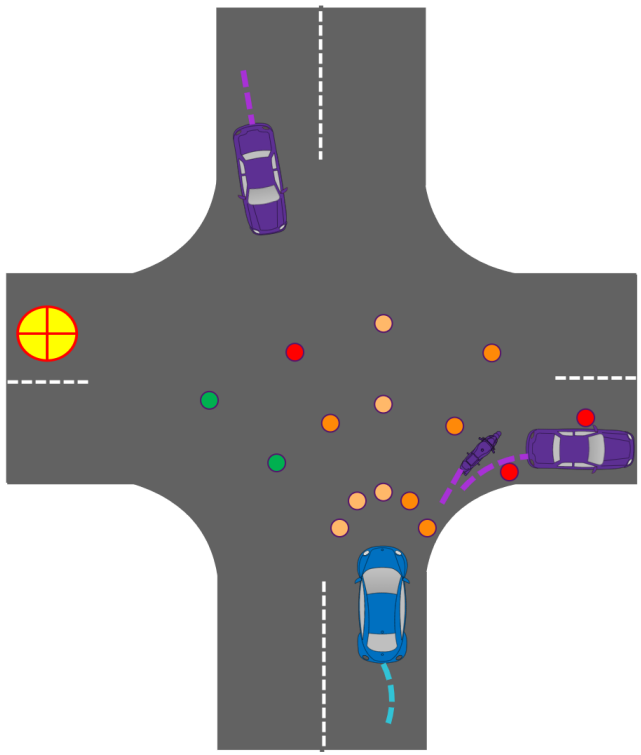
WayDCM

2. Target Prediction



Neural Network Prediction.

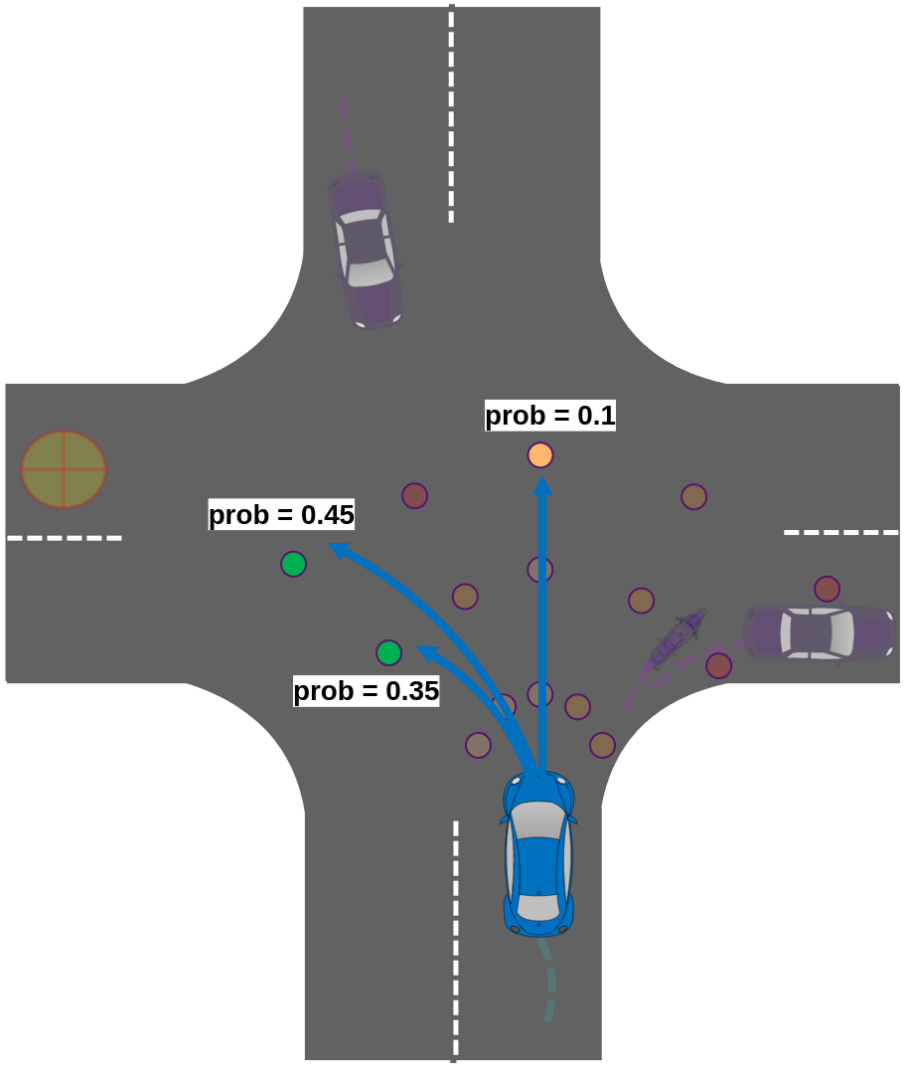
+



DCM Prediction.

WayDCM

3. Motion Estimation : Conditioned on goals.



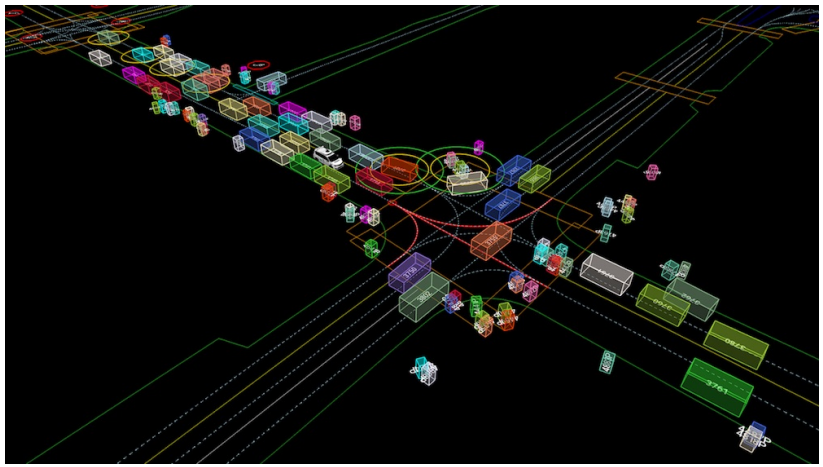
Waymo Dataset

Table: Past, future and prediction horizons on different motion prediction datasets

Dataset	Past (s)	Future (s)	Prediction (s)
nuScenes	3	5	5
INTERACTION	1	3	3
Argoverse 1	2	3	3
Argoverse 2	5	6	6
Waymo	**1**	**8**	**3, 5 and 8**

Waymo Dataset

- Provides 103,354, 20s 10Hz segments (over 20 million frames)
- Collected from diferent cities in the United States of America (San Francisco, Montain View, Los Angeles, Detroit, Seattle and Phoenix)



Past time horizon : 1 second
Prediction horizon : 3 seconds
Long term Waypoint : the position of agent at 8 seconds

Results

- $MinADE_6$: Average of pointwise L2 distances between the predicted trajectory and ground truth.
- $MinFDE_6$: Average of pointwise L2 distances between the final points of the prediction and ground truth.

Table: Comparison of different methods on the Waymo validation set

Model	$MinADE_6$	$MinFDE_6$
MotionCNN	0.3365	0.6145
MultiPath++	0.2692	0.4951
LSTM	0.4018	0.8029
MHA-LSTM	0.3141	0.7577
TrajDCM	0.3060	0.7201
WayDCM (without ddist)	0.2779	0.6261
WayDCM	**0.2721**	**0.6037**

Results

$$u_k = \beta_{dir} dir_k + \beta_{occ} occ_k + \beta_{col} col_k + \beta_{ddir} ddir_k + \beta_{ddist} ddist_k$$

Table: Estimated parameters β

Model	β_{dir}	β_{col}	β_{occ}	β_{dangle}	β_{ddist}
TrajDCM	-2.70	-0.07	-0.06	-	-
WayDCM (without ddist)	-3.48	-0.09	-0.04	**-15.23**	-
WayDCM	-2.64	-0.05	-0.06	**-10.83**	**-20.86**

Conclusion and future work

- Fist approach using Long Term Waypoints.
- Long Term Waypoints should be included in motion prediction datasets.
- For future work : use this approach with other goal set representations.

Thank you for your attention !