Social Attention for Autonomous Decision-Making in Dense Traffic

Edouard Leurent*, Jean Mercat*

GROUPE RENAULT

informatics mathematics Inria

Motivation

Behavioural Planning

- High-level decisions: lane, stop or go
- In interaction with other drivers

Reinforcement Learning

Optimal Control Ojective

$$Q^*(s,a) \stackrel{\text{def}}{=} \max_{\pi} \mathbb{E}\left[\sum_{t=0}^{\infty} \gamma^t R(s_t,a_t) \,\middle|\, \begin{smallmatrix} s_0=s \\ a_0=a \end{smallmatrix}\right]$$

Bellman Optimality Equation and DQN Algorithm

$$Q^*(s,a) = \mathop{\mathbb{E}}_{s'\sim P(s'|s,a)} \max_{a'\in A} \left[R(s,a) + \gamma Q^*(s',a')\right]$$

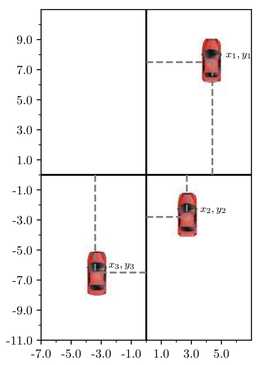
State Representation

Representing social interactions

A joint state s of $N+1$ observed vehicles

$$s = (s_i)_{i\in[0,N]}$$

$$s_i = \begin{bmatrix} x_i & y_i & v_i^x & v_i^y & \cos\psi_i & \sin\psi_i \end{bmatrix}^T$$



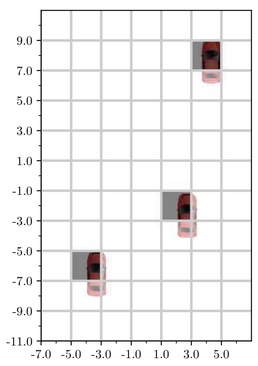
List of features representation

Issues related to function approximation

1. Variable size
   ↳ usual models accept fixed-size inputs
2. Sensitivity to the ordering
   ↳ we want the policy to be permutation-invariant:

$$\forall \tau \in \mathfrak{S}_N, \qquad \pi(\cdot|(s_0, s_1, \dots, s_N)) = \pi(\cdot|(s_0, s_{\tau(1)}, \dots, s_{\tau(N)}))$$

A common solution



Occupancy grid representation

- ✓ Fixed-size
- ✓ Does not depend on an ordering
- ✗ Suffers from an accuracy / size tradeoff

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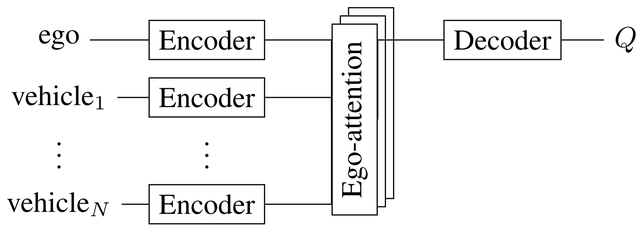
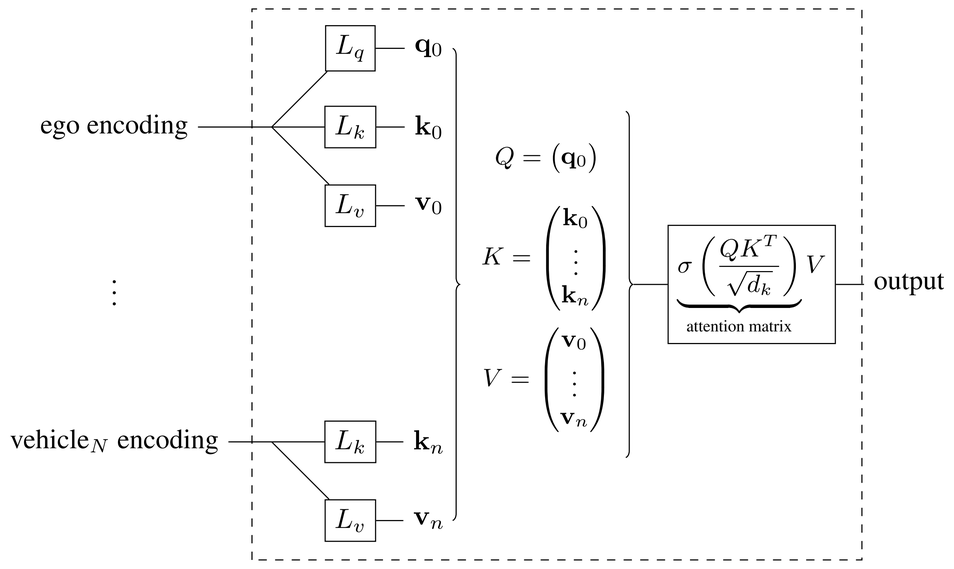
Model Architecture



Model architecture

- ✓ Inputs can have a variable size
- ✓ Based on a dot product
  ↳ permutation-invariant
- ✓ Compact size with no accuracy loss



Ego-attention block

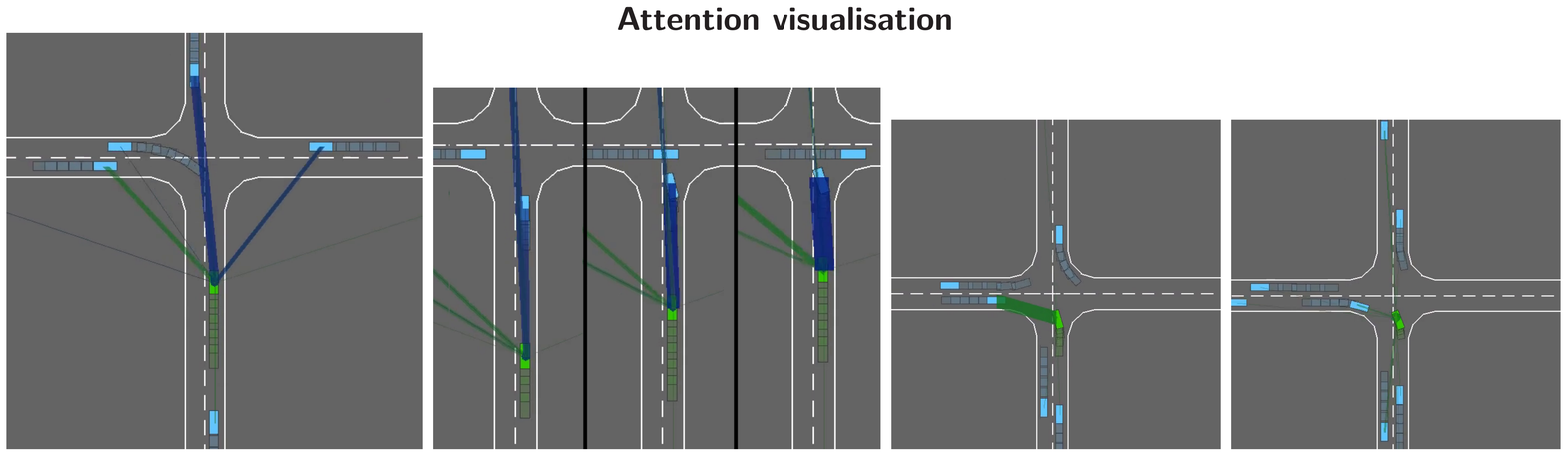
Experiments

Agents

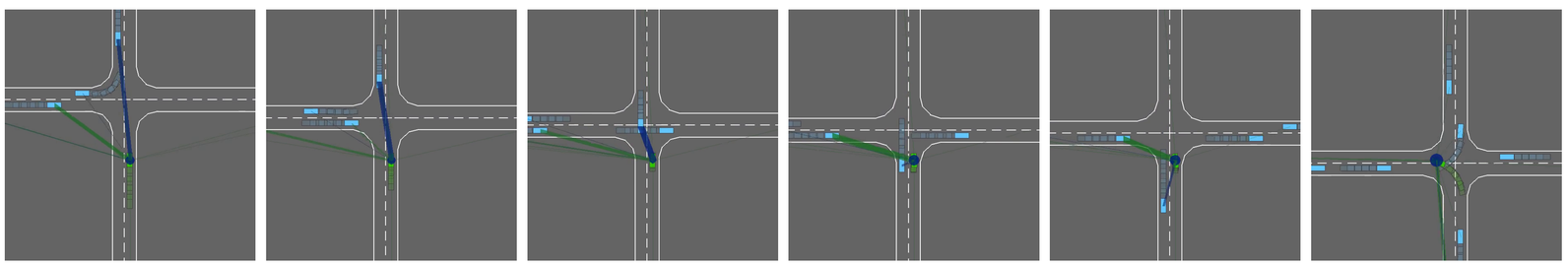
Agent	`FCN/List`	`CNN/Grid`	`Ego-Attention`
Input sizes	[15, 7]	[32, 32, 7]	[· , 7]
Layers sizes	[128, 128]	Convolutional layers: 3 Kernel Size: 2 Stride: 2 Head: [20]	Encoder: [64, 64] Attention: 2 heads $d_k = 32$ Decoder: [64, 64]
Number of parameters	3.0e4	3.2e4	3.4e4
Variable input size	No	No	Yes
Permutation invariant	No	Yes	Yes

Performances

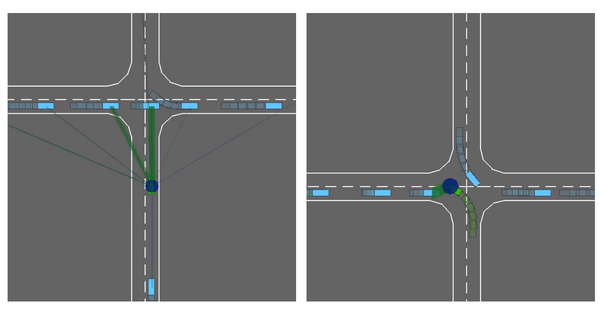
Attention visualisation



Head specialisation — Distance — Sensitivity to uncertainty



A full episode



Exploiting interaction patterns